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Milk Production from Plantain (*Plantago lanceolata* L.) Pastures

S. Navarrete, P.D. Kemp, M.J. Rodriguez, M.J. Hedley, D.J. Horne, and J.A. Hanly
School of Agriculture and Environment, Massey University, Palmerston North, New Zealand

Abstract

Incorporating plantain (*Plantago lanceolata*) pastures on dairy farms can mitigate nitrogen (N) loss from pastoral dairy systems. The merit of plantain to reduce N loss and its impact on milk production were evaluated in a dairy system experiment at Massey University’s Dairy Farm No 4. Sixty cows were selected to graze three pasture treatments: (i) plantain, or (ii) plantain-clovers mix, containing plantain, white clover (wc) and red clover (*Trifolium repens and T. pratense*), or (iii) perennial ryegrass (*Lolium perenne*)-wc throughout the 2017-2018 season. The pastures were grazed over 8-d grazing periods composed of an adaptation period (days 1 to 6) to the pasture diet followed by an experimental period (days 7 and 8) with cows grazing the plots. The pastures were established in a complete randomised design (n=5) in plots (800 m²) with isolated mole-pipe drain systems to collect drainage water samples and determine the nitrate leaching from each pasture treatment. Total milk solids production and milk urea of cows were evaluated in four grazing periods: December 2017 and February, March, and April 2018. After 8 days, cows fed both the plantain and plantain-clovers mix pastures produced the same milk solids as cows fed ryegrass-wc pasture. The urea production from cows fed plantain was lower from February to May 2018 than cows fed ryegrass/white clover pasture. The results from season 2017-2018 show plantain based pastures do not diminish milk solids production; therefore, if plantain can mitigate NO₃-N leaching it can be safely included in the cows’ diet.

Introduction

New Zealand pastoral dairy systems require technologies and good environmental practices to meet with future regulations that limit the nitrogen (N) loss, principally mitigation of nitrate (NO₃-N) leaching into ground waters from dairy farms. The largest contributor to N loss from dairy farms is the high N loading in urine patches by cows, being in surplus to N uptake for plants, leading to the N excess being lost in the form of NO₃-N leaching. Methods developed to better manage N leaching usually require extra money spent on supplements and housing or a loss of production (Christensen et al., 2012). Several researchers have consistently reported lower urinary N concentrations when cows grazed pastures containing plantain in the sward. Research under laboratory conditions showed that bioactive compounds in plantain (acteoside (syn. verbascoside) and aucubin) decreased ammonia (NH₃) loss in the rumen, which suggests their potential to reduce the amount of urinary urea excreted from cows (Navarrete et al., 2016). Reliance on low-cost pasture production systems in New Zealand creates the need to evaluate the plantain pasture option. Therefore, the objective of this research is to evaluate whether plantain (*Plantago lanceolata*) based pasture dairy systems decrease the N loss from dairy farming in comparison to traditional ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture while still increasing or maintaining milk production.
Materials and Methods

1.1 Experimental Site and treatments

The research was carried out at Massey University Dairy Farm No 4 in Palmerston North, New Zealand (40° 23' S; 175 ° 36' E) with the approval of Massey University Animal Ethics Committee (Protocol 16/137). Three pasture treatments were established on 1 December 2016 on a series of plots on Tokomaru silt loam soil and grazed by lactating dairy cows. Each plot was 40 x 20 m (800 m²) and has an isolated mole-pipe drain system to collect drainage water samples. The pasture treatments were sown as: (i) plantain, (ii) plantain-clovers mix, containing plantain, red clover (Trifolium pratense) and white clover (T. repens), and (iii) perennial ryegrass/white clover. There were five replicates of each treatment and these were laid out in a complete randomised design. Three additional paddocks (approximately 1 ha) of each pasture treatment were also established near the experimental plots. These additional paddocks were used to fully adapt the cows’ diet to the pasture treatments before grazing in the experimental plot treatments.

1.2 Cow management

Sixty lactating dairy cows were selected from the dairy farm and separated in three groups. Each group (n=20) grazed one of three pasture treatments over eight consecutive days from September 2017 to May 2018. During days 1 to 6 (adaptation period) cows were allocated to graze in the adaptation area in order to acclimatise cows to their experimental pasture treatments. Then, on day 7 and 8 each group of cows were transferred into the experimental plots (experimental period). Each plot was grazed by four cows, spending two days in each replicate plot.

Table 1. Grazing dates and supplementation of cows in each period.

<table>
<thead>
<tr>
<th>Grazing Period</th>
<th>Grazing Date</th>
<th>Supplementation¹ (kg DM/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
<td>29th November to 6th December</td>
<td>6.5</td>
</tr>
<tr>
<td>February</td>
<td>1st to 8th February</td>
<td>5</td>
</tr>
<tr>
<td>March</td>
<td>1st to 8th March</td>
<td>7</td>
</tr>
<tr>
<td>May</td>
<td>26th April to 3rd May</td>
<td>7</td>
</tr>
</tbody>
</table>

¹ Supplements were Maize silage, Pasture baleage, Dairy pellet, and Dried Distillers Grains (DDG)

1.3 Measurements

1.3.1 Pasture treatments

The herbage mass (kg DM/ha) pre- and post-grazing and the botanical composition pre-grazing were determined by cutting to ground level (0.1 m² quadrats) three samples randomly chosen from each experimental plot using an electric shearing handpiece. The pre- and post-grazing samples were washed to remove soil contamination and oven dried at 70 °C for approximately 48 h. The botanical samples were manually separated into each species and dead material, oven-dried individually at 70 °C. After 48 h, all samples were weighed and the pasture intake and proportion for each species in the DM were calculated. One grab sample (200 g fresh weight) from each plot was
used for nutritive analysis of crude protein (CP), metabolisable energy (ME), neutral detergent fibre (NDF), and soluble sugars (SS).

1.3.2 Cows

Milk volume (L/day) was recorded daily during each grazing period. Cows were milked twice daily (0700 and 1430) in September 2017 and once a day (0700) from December 2017 to May 2018. Milk samples were collected for each cow at the milking on days 1 and day 8 to analyse milk solids and urea concentration. Urine samples were taken for each cow, immediately after the morning milking, on days 7 and 8 to analyse urea concentration.

1.4 Statistical analysis

Data were analysed using the PROC MIXED procedure of SAS 9.4 (SAS Institute, 2009) using a model for a complete randomise design. Means were compared using the least squares means test and significance was declared at \( P<0.05 \).

Results

Pasture DM intake (DMI) from cows and metabolisable energy (ME), crude protein (CP), and soluble sugars (SS) concentration in the three pasture treatments are presented in Table 2. The pasture DMI (kg DM/d) from grazing cows was similar between ryegrass-wc, plantain, and plantain-clovers mix pastures at every grazing period (Table 2). There was no difference in ME concentration between the three pasture treatments, except in December. The ME concentration in December was higher for ryegrass-wc compared to plantain and plantain-clovers mix pastures (Table 2). The NDF concentration was consistently higher in ryegrass-wc pasture than plantain and plantain-clover mix pastures. Ryegrass-wc and plantain-clovers had higher CP concentration than plantain in December, but in February and May both plantain and ryegrass-wc showed lower CP concentration compared to plantain-clovers mix. The CP concentration was similar between the three pasture treatments in March.

Table 2. Pasture intake and metabolisable energy (ME), crude protein (CP), neutral detergent fibre (NDF), and soluble sugars (SS) concentration in ryegrass-white clover (wc), plantain, and plantain-clovers mix pastures.

<table>
<thead>
<tr>
<th>Pasture Treatments</th>
<th>Ryegrass-wc</th>
<th>Plantain</th>
<th>Plantain-Clovers</th>
<th>SEM(^1)</th>
<th>( \text{P value} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture Intake (kg DM/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td>9.1</td>
<td>10.8</td>
<td>14.8</td>
<td>2.01</td>
<td>0.21</td>
</tr>
<tr>
<td>Feb</td>
<td>12.6</td>
<td>19.9</td>
<td>m.v(^2)</td>
<td>2.29</td>
<td>0.11</td>
</tr>
<tr>
<td>Mar</td>
<td>8.4</td>
<td>7.9</td>
<td>12.8</td>
<td>1.51</td>
<td>0.09</td>
</tr>
<tr>
<td>May</td>
<td>8.0</td>
<td>6.8</td>
<td>7.5</td>
<td>1.52</td>
<td>0.72</td>
</tr>
<tr>
<td>ME (MJ/Kg DM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td>10.9(^a)</td>
<td>10.3(^b)</td>
<td>10.3(^b)</td>
<td>0.08</td>
<td>0.003</td>
</tr>
<tr>
<td>Feb</td>
<td>9.8</td>
<td>9.6</td>
<td>9.9</td>
<td>0.13</td>
<td>0.38</td>
</tr>
<tr>
<td>Mar</td>
<td>9.4</td>
<td>9.6</td>
<td>9.4</td>
<td>0.28</td>
<td>0.82</td>
</tr>
<tr>
<td>May</td>
<td>10.5</td>
<td>10.8</td>
<td>10.4</td>
<td>0.14</td>
<td>0.22</td>
</tr>
</tbody>
</table>
Milk solids production (kg MS/cow/day) from dairy cows fed plantain, plantain-clovers mix, and ryegrass-wc pastures are presented in Table 3. The total milk solids production (kg MS/cow/day) was similar (P>0.05) between the three pasture treatments at each grazing period. The MUN was similar between pasture treatments in December. In February, the milk urea in cows grazing the plantain-clovers mix pasture was higher than for those grazing either plantain or ryegrass/wc pastures. However, cows grazing in plantain excreted less urea in the milk than cows grazing in plantain-clovers mix and ryegrass-wc pastures both in March and in May. The urea concentration in the urine for cows grazing plantain and plantain-clovers mix pastures was significantly lower compared to ryegrass-wc pasture both in February and March, but was similar for the three pasture treatments in December (Figure 1).

Table 3. Milk solids (MS) production and milk urea (MUN) from cows after 8 days grazing in ryegrass-white clover (wc), plantain, and plantain-clovers mix pastures in the milking season 2017-2018.
Table 1. Urinary urea concentrations (mmol/L) in the urine of cows grazing plantain, plantain-clovers mix and ryegrass-white clover (wc) pasture in the December 2017, and February and March 2018 grazing periods.

<table>
<thead>
<tr>
<th></th>
<th>Mar-18</th>
<th>May-18</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.93&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>2.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.36&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>2.42&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.12&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>0.149</td>
<td>0.221</td>
</tr>
<tr>
<td></td>
<td>0.0004</td>
<td>0.005</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> superscripts indicate values within row that are significantly (P<0.05) different.

<sup>1</sup>SEM, standard error of the mean.

Figure 1. Urinary urea concentration in the urine of cows grazing plantain, plantain-clovers mix and ryegrass-white clover (wc) pasture in the December 2017, and February and March 2018 grazing periods.

Discussion

The incorporation of plantain pastures in dairy farming can provide NZ farmers with a low cost solution to mitigate N loss to the environment. Farmers will adopt the use of plantain if the benefit of lowering N losses also sustains, or increases, milk production. In the current research, the milk solids production when cows grazed both plantain and plantain-clovers based-pastures was similar to that of ryegrass-wc based-pastures. Short term studies on plantain have consistently reported a urinary N concentration 25-50% lower, when cows graze diverse pastures containing plantain in the sward compared to perennial ryegrass pasture, thus minimising the N leaching from pasture-based systems (Totty et al., 2013; Edwards et al., 2015; Bryant et al., 2016; Box et al, 2018). Recent research has reported that grazing new plantain-based pasture in autumn reduced the N leaching by 90% in the winter drainage compared to perennial ryegrass-wc pasture, but the overall quantity of N leached was low in all pastures due to the effects of setting up the experimental site on soil N (Navarrete et al., 2018). The lower CP and high SS concentration in plantain at least partly explained the lower urinary N concentration on cows grazing plantain pastures (Pacheco et al., 2010). Bioactive compounds (aucubin and acteoside) in plantain could also lower ammonia (NH<sub>3</sub>) production in the rumen and reduce the amount of urinary urea and total N excreted by cows when grazing plantain (Navarrete et al., 2016). In this research, the urea concentration in cows’ urine was lower for plantain and plantain-clovers mix pastures than ryegrass-wc during the February and March grazing periods. However, the MUN was lower for plantain than for plantain-clovers mix and ryegrass-wc in March and May. The diet CP concentration is the main driver of MUN and urinary N excreted by cows. However, the higher CP concentration in plantain-clovers mix and the similar MUN between plantain-clovers mix and ryegrass-wc indicated that multiple factors are playing a role in lowering urea production in cows grazing...
plantain. Previous work has also shown a relationship between MUN and urinary urea concentration (Spek et al., 2013). Therefore, if plantain is conclusively shown to mitigate the N leaching from dairy pastoral systems it could be included as a successful low cost option to reduce the environmental impact of NZ dairy systems.

**Conclusions**

This research demonstrates that plantain based-pastures can be included in cows’ diets to create lower urinary urea without loss in milk production. The introduction of Plantain-based pastures in dairy farming is likely to provide a low cost forage option with the potential value to reduce the environment footprint from NZ pastoral dairy systems.

**References**


Pasture Measurement Data Improves Timeliness and Confidence in Grazing Management Decisions

Lesley Irvine & Lydia Turner
Tasmanian Institute of Agriculture, University of Tasmania, Cradle Coast Campus, Burnie 7320, Australia

Summary

Dairy farmers may be able to increase farm profitability by obtaining pasture measurement data. Four Tasmanian dairy farmers participated in an eighteen-month study investigating the value of accessing regular pasture measurements. The farmers reported an increased confidence in their visual observations of pasture covers by having access to the provided data and for three of the four farmers this has led to an estimated improvement in profitability ranging from $90/ha to $550/ha.

Abstract

Pasture consumption is a key driver of dairy farm profitability in temperate dairying regions, including New Zealand and Tasmania. Grazing management has been a focus of Tasmanian dairy extension activities for over four decades and during this time there has been significant improvements in pasture consumption. However, there are still large gaps between the upper limit of pasture consumption achieved through experimental research and modelling, and the maximum pasture consumption advanced Tasmanian dairy farmers achieve in practice. A Participatory Action Research (PAR) approach was applied to test whether it was possible to further increase pasture consumption on farm, and to identify key factors that would help decrease the gap between possible and currently achieved levels of pasture consumption. The PAR group included farmers, advisors, researchers and an extension officer. Regularly measuring pasture biomass was identified by the PAR group as the practice most likely to offer biggest gains in pasture consumption. Four advanced pasture managers, already achieving high pasture consumption on their farms, participated in an 18-month study to determine the impact of regularly receiving pasture measurement data upon their grazing management decisions and farm pasture consumption. The study aimed to evaluate the value and effect of access to regular individual paddock biomass and pasture growth rate data. For three of the four participating farmers, regularly receiving data was valued between $90/ha and $550/ha and led to more accurate and confident decision making.

Keywords

Pasture consumption, Tasmanian dairy industry, Monitoring

Introduction

Pasture consumption is a key driver of dairy farm profitability in pasture-based dairy systems (Moran 2000, Rawnsley et al 2007), and for the past 30-40 years research, development and extension in Tasmania has focused upon improving on-farm pasture consumption. From 2006-07 to 2016-17 average pasture consumption on benchmarking Tasmanian dairy farms has increased from 8.5 t DM/ha to 10.6 t DM/ha (Tasmanian Institute of Agriculture 2018). While this is a significant improvement, it is still well below what is theoretically possible (Rawnsley et al 2007). Recent Tasmanian dairy feedbase research projects (20.12; Beyond 20.12; More Milk From Forages) have successfully investigated how to lift the theoretical ceiling of pasture consumption. However, there is still a large gap between that achieved on-farm and what is currently theoretically possible. The
highest level of pasture consumption recorded in Tasmania in 2016-17 was 15 t DM/ha (Dairy Australia Limited 2018).

The Dairy On PAR project used a Participatory Action Research (PAR) approach to address the challenge of increasing home-grown forage consumption. A PAR group was established which involved seven farmers, a milk supply officer, agronomist, consultant, extension officer, social researcher, feedback researcher, feedbase technical officer, and the feedbase manager for the project funding body (Dairy Australia). Each participant had a high level of expertise in crop and/or pasture management. This group reviewed their existing knowledge relating to home-grown forage consumption then identified and prioritised key opportunities for improving forage consumption levels. The greatest opportunity, identified by the PAR group, was regular measuring and monitoring of pasture biomass to aid in grazing management decisions. A research project was developed to investigate whether access to regular pasture biomass data could improve the grazing management decisions of farmers who already had a high level of grazing expertise and if so, to establish the value of these improved decisions.

Methods

Four farmers from the PAR group participated. One of these farmers had recently stopped regular pasture measurements because of equipment break-down. Two farmers had undertaken regular measurements in the past (> 5 years ago) but were no longer measuring pastures and were relying on accurate visual assessments. The fourth farmer had regularly measured pasture in the past but now measured pasture only at critical points in the season.

Qualitative data were collected from each farmer through face-to-face, semi-structured in-depth interviews at key intervals during the study. Interviews were conducted prior to project start, at the mid-point and at the project conclusion. Informal monitoring was conducted via phone in-between the more formal interviews.

Interviews, prior to project commencement, collected information relating to existing pasture management practices and included: how rotation length was determined, how feed was allocated and how decisions were made in relation to the timing of nitrogen applications, closure of silage and hay paddocks and irrigation start-up. Follow-up interviews investigated how farmers had used the data, how they viewed the reliability of the data, which (if any) pasture management decisions were impacted as a result of ready access to data and the estimated value of the data to their farm operations. The formal interviews were digitally recorded and transcribed. Notes from the informal phone interviews were made by the interviewer. The research was approved by the University of Tasmania Social Science Ethics Committee (H0015305).

Technical officers employed by the Tasmanian Institute of Agriculture visited each farm on a weekly basis during spring, summer and autumn and fortnightly during the winter period when cows were not lactating. This occurred over an 18-month period, with the technical officers measuring the pasture biomass using a rising plate meter (Farmworks Systems, Feilding, New Zealand). The time taken on each occasion, and hence cost, of undertaking the farm walk to collect the pasture biomass depended on the farm size and topography. It ranged from 3 hours to 5 hours (approximate cost of $0.60 to $1.20/ha). The pasture biomass (kg DM/ha) and growth rate (kg DM/ha.day) for each paddock on the milking platform of each farm was provided to the farmer via email as both an Excel spreadsheet and a feedwedge in the online pasture management tool Pasture.io (https://pasture.io).
Results

All four farmers reported checking and reviewing the data when it arrived, with each farmer then using the data in a different manner (Table 1). After the initial period of measuring, Farmer 1 developed a preference for monitoring his farm’s average pasture cover and growth rate and did not use the individual paddock data provided. Farmer 2 used individual paddock data to rank paddocks in a feed wedge using a homemade Excel spreadsheet. Data supplied was then used to calculate potential cow intakes, determine supplement required and develop the weekly grazing plan. Farmer 3 looked at individual paddock data to confirm the validity of decisions currently being made and based on visual assessment of pasture covers. Farmer 4 used an online commercial program (Pasture.io) to calculate cow intake and to adjust supplementary feeding as required.

Despite the differences in how the data was being used, all the farmers reported using the data in conjunction with visual assessments of their pasture; none solely relied on the data supplied. As Farmer 2 explained “So I get that information, put together – you know look at the grazing rotation, where they’ve been, where they’re due to go, look at the amount of feed that’s on the feed wedge, put a bit of a plan together. And then hop on the bike and go and ride around and make sure that’s right. Then I’ll come back and change it if need be.”

Table 1. Pasture measurement data usage and value of data for each of the four farmers in the study.

<table>
<thead>
<tr>
<th></th>
<th>Farmer 1</th>
<th>Farmer 2</th>
<th>Farmer 3</th>
<th>Farmer 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herd size</td>
<td>725</td>
<td>500</td>
<td>1020</td>
<td>430</td>
</tr>
<tr>
<td>Milking area</td>
<td>260</td>
<td>124</td>
<td>260</td>
<td>123</td>
</tr>
<tr>
<td>Regular measurement of pasture at some point in the past</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Regular measurement of pasture within 6 months of project start</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Looked at the data when it was sent through each week</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Used individual paddock data to set grazing order of paddocks for the upcoming week</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Used individual paddock data to allocate feed for the milking herd</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Having access to data changed decisions relating to nitrogen applications</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Having access to data changed decisions relating to silage production</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Having access to data changed decisions relating to grazing residual management</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Having access to data changed decisions relating to irrigation management</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Planned to continue regular pasture measurements after project concluded</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Improved confidence in decisions made</td>
<td>YES</td>
<td>-</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Estimated financial value of regular pasture measurement data to their business</td>
<td>NONE</td>
<td>$90/ha</td>
<td>$180/ha</td>
<td>$550/ha</td>
</tr>
</tbody>
</table>
Three of the four farmers reported there was financial value to their business in having access to regular pasture biomass and growth rate data. Each of these three farmers valued the information to the extent that they would pay someone outside of their farm team to physically collect the data. As Farmer 4 explained “It’s not a very big cost to do it really, and it’s hard to put a price on making a decision earlier... So if you make your decisions earlier and with more surety that 60 bucks a week could make you $60 or $80,000 a year, with ease... if you drop a few paddocks at the right time you’re getting better regrowth, the cows milk better, plus you don’t have to buy so much bought in feed. You get a double win.”

Farmers 2-4 estimated the (gross) return they would receive from investing in measuring and monitoring their pasture ranged from $90/ha to $550/ha. The individual farmers estimates were based on the decisions they made by having access to regular pasture biomass and growth rate data. In their estimate, the farmers focused particularly on the extra pasture consumption they attributed to improved management from using the data. Farmer 4 used the data more intensively than the other participants and was able to account for savings made on purchased feed by increasing pasture consumption and improved pasture quality.

Farmer 1 did not find having access to regular pasture biomass and growth rate data of financial value and found his approach to decision-making did not change. However, the data did reinforce what he was seeing: “…what it does, it does help gut feeling; like it confirms what you’re feeling and what you’re seeing on the farm.”

Farmer 3 also used the data in conjunction with his visual assessment and reported that it increased his confidence in those observations: “You know the first thing I do is look at the cover and the growth rate, and then I sort of glance through the paddocks. ...it’s a really good indicator of what’s going on. It backs up what we feel is happening. ...it meant I’ve got more confidence in what I’m seeing on a paddock. And sometimes I think, oh that’s exactly what I think. Sometimes I think, oh that seems a bit low or a bit high. But it’s still being useful.”

Having greater confidence led Farmer 4 to be more proactive with decision-making, in particular silage conservation: “…the earlier you can cut it and get it off the better it is... So in that regard it [the data] helps a lot. And I was always way too conservative in making that decision because I always wanted to fully feed the cows. So I was ultra-conservative in dropping paddocks.” And this led to improvements in milk production: “But definitely making better decisions [using the data] with cutting silage earlier to keep quality and that makes a difference in the vat.”

Discussion

The Dairy On PAR project recognised the need for farmers to participate in the research process to further increase pasture consumption on Tasmanian dairy farms. In this participatory approach, hypotheses and research questions were developed jointly between farmers, industry service providers and scientists and as the PAR process progressed, results from the research were jointly interpreted to develop actions for further investigation and/or implementation on-farm (Ashby and Lilja 2004). The PAR group prioritised investigating the value of measuring and monitoring pasture, agreeing this offered the greatest potential to increase the amount of homegrown forage consumed. Despite the participating farmers already being expert pasture managers, fine tuning grazing management was the first practice chosen to decrease the gap between on-farm pasture consumption and the theoretical ceiling of pasture consumption.

The farmers participating in the measuring and monitoring study had previously been through a period of intensive learning (12 month pasture coaching program) involving the extended, deliberate practice required to deliver expert performance (Ericsson and Lehmann 1996). The
intensive learning was undertaken within a coaching program involving farmers using pasture measuring tools during a 12-month period, since then tool use had decreased significantly. Instead, grazing management decisions were being made based on observation and informed intuition. As Prietula and Simon’s (1989) point out, ‘intuition is not the opposite of rationality, nor is it a random process of guessing. It is a sophisticated form of reasoning...that an expert hones over years of job-specific experience.’

Even with highly developed expertise and the use of intuitive decision making, all four farmers participating in the project found receiving pasture biomass and growth rate data on a regular basis improved confidence in the decisions they were making about grazing management. Improved confidence led to timely decisions being made, particularly in fodder conservation with flow-on effects of improved silage quality, pasture re-growth, milk production and reduced need for purchased supplements. It is important to note, data did not replace observations. Each of the four farmers continued to make visual observations of pasture biomass and growth and used this in conjunction with provided data. Eastwood and Kenny (2009) reported a similar result in their pilot study, where pasture biomass and growth rate data from satellites was provided to dairy farmers and rather than relying only on the provided data, farmers used the data to reinforce their own method of decision-making.

Three of the four farmers involved in the study believed having access to pasture measurement data improved financial returns of their business. There was a large range in the estimated value of the provided data, from $90/ha to $550/ha, but even the lowest value would be a return 2-3 times greater than the cost of obtaining the measurements. These estimates are similar to those found in a farm-scale simulation exercise conducted by Beukes et al (2018). In their study, ‘imperfect knowledge’ of pasture biomass increased farm operating profit by $NZ385/ha above ‘low knowledge’. ‘Perfect knowledge’ increased farm operating profit a further $NZ155/ha.

This study demonstrated the value of regularly obtaining and using pasture biomass and growth rate data – even for expert farmers. With increasing ease of access to this data (SPACE™, Pasture.io) there is a large potential for further increases in pasture consumption in the Tasmanian dairy industry. However, just providing access to data will not ensure it will be used or perhaps even understood (Turner et al, submitted).

Conflicts Of Interest

The authors declare no conflicts of interest.

Acknowledgements

The authors thank the dairy farmers for their participation in the project. Thank you also to Carlton Gee, Hamilton Wakefield, Nathan Bakker and Susan Walker for undertaking the weekly on-farm pasture measurements. The authors are also grateful to the input from all the members of the Dairy On PAR participatory action research group. The Dairy On PAR project was funded by Dairy Australia and the Tasmanian Institute of Agriculture (Grant Number C10001341).

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Grain type offered to lactating cows during a heat challenge affects forage consumption

Agriculture Victoria Research, Ellinbank, Vic. 3821, Australia

*Corresponding author: Email: leah.marett@ecodev.vic.gov.au

Short Title: Dry matter intake during heat stress

Abstract

Eighteen second lactation Holstein-Friesian cows (mean ± s.d.; 20.7 ± 2.41 L/day milk, 558 ± 37.0 kg bodyweight) were allocated to one of two dietary treatments. Cows were individually offered 14 kg DM chopped lucerne hay plus 6 kg DM/day of crushed wheat (WHT) or crushed corn (CRN). Treatment groups were balanced for body weight and milk yield. Dry matter intake (DMI) of hay and grain, milk yield and milk composition were measured for a 7-d baseline period at ambient conditions and a 4-day heat challenge. The temperature humidity index for the heat challenge ranged from 74 to 84 in individual controlled-climate chambers. Mean data for baseline and heat challenge were subjected to ANCOVA separately for each period. There were no treatment differences in total DMI, milk yield or composition during the baseline period. During the heat challenge, CRN cows had greater intake of hay (11.5 vs. 9.9 ± 0.56 kg, \( P = 0.016 \)) but not grain (5.9 vs. 5.9 ± 0.07 kg, \( P = 0.441 \)) compared to the WHT cows. There was no difference in milk production due to treatment. Changing the concentrate type offered to lactating cows may improve forage consumption during periods of hot weather.

Additional keywords

heat stress; nutrition; dairy cow; intake

Introduction

Lactating dairy cows are among the most susceptible of all domesticated production animals to the negative impacts of hot weather (Collier et al. 1982; Kadzere et al. 2002). This is an important issue for the Australian dairy industry with future climate scenarios predicting hotter and more variable climates (Forster et al. 2007). Reduced feed intake partly explains the biological mechanism by which heat stress impacts milk production (Bernabucci et al. 2010). Pair feeding experiments have shown that between 35% (Rhoads et al. 2009) and 50% (Wheelock et al. 2010) of the reduction in milk yield induced by heat stress is attributed to reduced nutrient intake. Other major factors are either poorly understood or not yet identified.

Dry matter intake can be modified by the nature and amount of feed consumed. The rate and extent of fermentation of a feed impacts heat production and VFA utilization (MacRae and Lobely, 1982). Feeds such as corn grain have a slow rate of ruminal degradation while wheat grain is rapidly degraded in the rumen (Offner et al. 2003). Moate et al. (2018) reported greater dry matter intakes and greater milk production in cows fed corn compared to wheat grain. Core body temperature (Gonzales-Rivas et al. 2018) and skin temperature (Bland et al. 2013) may be reduced by offering cows...
corn grain in place of wheat grain. The grain type that is offered to the lactating cow may impact feed intake, milk production and body temperature during heat exposure.

This research aimed to determine whether cereal grains with different ruminal degradability characteristics influence dry matter intake and milk production of cows exposed to a heat challenge. We hypothesized that cows fed corn grain would have i) a smaller reduction in feed intake, ii) a smaller loss in milk yield, and iii) a lower body temperature during a heat challenge than cows fed wheat grain.

**Materials and methods**

The experiment was conducted at Agriculture Victoria Research, Ellinbank Centre in Victoria, Australia (latitude 38°14'S, longitude 145°56'E). All procedures were approved by Department of Economic Development, Jobs, Transport and Resources Agricultural Research and Extension Animal Ethics Committee.

1.5 Cows and design

Eighteen second lactation, pregnant, Holstein-Friesian cows (20.7 ± 2.41 L/day milk yield, 220 ± 94.2 DIM, 558 ± 37.0 kg BW; mean ± s.d.) were allocated to one of three cohorts (based on body weight) and randomly assigned one of two dietary treatments; 6 kg DM/day of crushed corn grain (CRN; slow rumen degradable), or 6 kg DM/day of crushed wheat grain (WHT; fast rumen degradable) supplemented diet. Cows in both treatments were offered 14 kg DM/d of chopped lucerne hay, 42 mL/d bloat drench (VicChem, Coolaroo, Vic, Australia), 100 g/d salt, and 200 g/d minerals.

Each treatment was allocated at random to three of the six cows within each cohort, subject to overall treatment group balance for bodyweight, milk yield, and DIM. This was achieved using the COVDESIGN procedure in GenStat 18 (VSN International, Hemel Hempstead, UK). Within cohort, cows were then randomly allocated to one of six controlled-climate chambers. Start date for each cohort was staggered due to availability of 6 chambers.

The experiment consisted of four periods. During the 7-d covariate period at ambient conditions, all cows were offered a common diet of 14 kg DM/d of chopped lucerne hay and 3 kg DM/d of each of corn and wheat grain (total 6 kg DM/d grain). During the 7-d adaptation period at ambient conditions, cows were transitioned to the treatment diets. Cows were offered the full treatment ration during the 7-d baseline period at ambient conditions. During the first three periods, cows were fed their rations in individual feed stalls. At the end of the third period, each cow was re-located to one of six controlled-climate chambers (No Pollution Industrial Systems, Edinburgh, UK), offered the same ration and was exposed to a heat challenge for 4-d following protocols developed by Garner et al. (2016). Cows were fed and milked in the chambers.

During the experiment each cow was individually offered 50% of the forage and concentrate following the morning and afternoon milkings. Within the covariate, adaptation and baseline periods cows were given 3 hr after each milking to consume their ration, with access to water at least once, before being returned to a loafing area with soft bedding, shade and *ad libitum* water. Cows were fed their grain during milking, with forage offered immediately after and water available *ad libitum* during the heat challenge period.

The conditions in the chambers for the heat challenge were designed to keep the temperature-humidity index (THI) above 74 and not to exceed THI 84 so to impose a mild to moderate level of heat stress. The climatic conditions programmed into the control system were 25°C and 60% RH (THI 74)
between 1800 hours and 0600 hours, 30°C and 50% RH (THI 80) between 0600 hours and 1200 hours, and 33°C and 50% RH (THI 84) between 1200 hours and 1800 hours. The cycle of 12 hours light and 12 hours dark was controlled manually. The THI was calculated using equation (1) (Yousef 1985):

\[
THI = Tdb + (0.36 \times \frac{\log_{10} \frac{RH}{100} + \frac{17.27 \times Tdb}{237.3 + Tdb}}{1.0 - \frac{\log_{10} \frac{RH}{100} + \frac{17.27 \times Tdb}{237.3 + Tdb}}{17.27}}) + 41.2
\]

Where Tdb = dry bulb temperature, RH = relative humidity

1.6 Measurements and sampling

The weight of grain and lucerne hay offered and refused were recorded twice daily per cow during all experimental periods. Samples of feed offered and refused were collected twice daily, for analyses of dry matter and chemical composition. Samples were freeze dried, ground to pass through a 0.5 mm screen and analysed for DM, crude protein, acid detergent fibre, neutral detergent fibre, lignin, non-fibre carbohydrate, starch, crude fat, ash, and estimated metabolisable energy (Dairy One, USA).

Table 1. Mean nutritive characteristics of feed components including crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), non-fibre carbohydrate (NFC), crude fat (CF) and metabolizable energy (ME). Data are means (% of DM unless otherwise indicated).

<table>
<thead>
<tr>
<th>Feed Component</th>
<th>CP</th>
<th>ADF</th>
<th>NDF</th>
<th>Lignin</th>
<th>NFC</th>
<th>Starch</th>
<th>CF</th>
<th>Ash</th>
<th>ME (MJ/kg DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed corn</td>
<td>9.0</td>
<td>2.6</td>
<td>6.3</td>
<td>0.7</td>
<td>80.0</td>
<td>74.1</td>
<td>3.7</td>
<td>1.1</td>
<td>14.6</td>
</tr>
<tr>
<td>Crushed wheat</td>
<td>13.6</td>
<td>3.2</td>
<td>8.8</td>
<td>0.8</td>
<td>66.7</td>
<td>61.6</td>
<td>1.8</td>
<td>2.3</td>
<td>13.2</td>
</tr>
<tr>
<td>Lucerne hay</td>
<td>18.6</td>
<td>36.1</td>
<td>44.7</td>
<td>8.7</td>
<td>25.8</td>
<td>0.9</td>
<td>1.6</td>
<td>9.3</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Cows were milked twice daily at 0600 and 1500 hours, with yield recorded automatically (MM25; DeLaval International, Tumba, Sweden) at each milking for all experimental periods except the heat challenge. During the heat challenge, each cow was milked using the inbuilt milking system (same clusters and pulsators as the milking parlour), and yields were recorded manually by weighing.

Milk composition (fat, protein, lactose) was analysed by near-infrared milk analyser (Model 2000, Bently Instruments, Chaska, MN, USA). Energy corrected milk (ECM) was calculated using equation (2) (Tyrrell and Reid 1965).

\[
ECM (kg/cow.day) = \frac{\text{milk yield (kg)} \times (376 \times \text{fat%} + 209 \times \text{protein%} + 948)}{3138}
\]

Rectal temperature of each cow was measured on two days during the baseline period and every day during the heat challenge at ~1500 hours using a digital thermometer (212771 large-animal digital thermometer; Shoof International, Cambridge, New Zealand).
Ambient weather conditions were measured with a weather station (J3504; MEA, Magill, SA, Australia) which recorded temperature and relative humidity.

1.7 Statistical Analyses
Data were summarized as means for each cow within the covariate, baseline, and heat challenge periods, by averaging over days within periods. The data for baseline and heat challenge periods were then subjected to ANCOVA using the covariate period data. The treatment structure for the ANCOVA was diet, and the blocking structure was cow nested within cohort. Changes between baseline and chamber, were calculated using the summary means for each cow, and also by using data for heat day 4 only. These changes were separately subjected to ANOVA, using the same treatment and blocking structures as above, but without covariate.

Results

1.8 Ambient conditions
During the baseline period the ambient weather conditions were: mean (± SED) air temperature of 17.1 ± 3.42°C (range 11.5 to 23.8 °C), relative humidity of 70.0% (range 43.5 to 92.2%), and mean THI of 63.5 (range 55.8 to 71.6).

1.9 Feed intake
The mean total DMI, total ME intake and the intake of dietary components (grain and hay) during the 7-day baseline period were not affected by treatment (P > 0.05; Table 2).

Exposure of cows to the 4-day heat challenge resulted in a reduction in the mean DM intake of grain, lucerne hay, total DM and ME compared to baseline (P < 0.01). The mean daily total DMI during the heat challenge was reduced to a lesser extent in the CRN compared to WHT cows (P < 0.05; Table 2). Moreover, the reduction in total DM intake in the WHT cows was mainly due to lucerne intake, with the lucerne intake of the WHT cows less than that of the CRN (P < 0.05). The DM intake of grain during the heat challenge was not affected by treatment. On day 4 of the heat challenge, total daily DMI was greater in the CRN cows compared to the WHT cows (16.4 vs. 12.9 kg DM/day ± 0.54; P = 0.002).

Lucerne hay made up 67% of the total DMI during the baseline period in both treatments, but during the heat challenge, lucerne hay constituted 66% of total DMI in the CRN cows, and 62% in the WHT cows.

Table 2. Mean daily dry matter (DM) and metabolizable (ME) intake of grain (crushed corn or wheat) and forage (lucerne hay) of cows in the CRN or WHT treatments during the baseline and heat challenge periods.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline</th>
<th>Heat Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CRI</td>
<td>WH</td>
</tr>
<tr>
<td>Grain intake (kg DM/day)</td>
<td>6.2</td>
<td>6.2</td>
</tr>
</tbody>
</table>
Forage intake (kg DM/day) 12.8 12.7 0.0 0.20 11.5 9.9 0.5 0.01
Total DM intake (kg DM/day) 19.1 19.0 0.0 0.12 17.4 15.8 0.5 0.02
Total ME intake (MJ/day) 207 207 0.30 190 176 4.0 0.01

Means in the same row followed by different superscripts differ (P < 0.05)

1.10 Milk yield and composition

During the 7-day baseline period, the mean daily milk yield, ECM yield, yields of milk components and milk composition were not affected by treatment (P > 0.05; Table 3).

Exposure of cows to the 4-day heat challenge resulted in a reduction in daily milk yield and yields of milk components (P < 0.05), except milk fat. During the heat challenge, mean daily milk yield (17.8 vs. 16.4 ± 0.92 kg/d; P = 0.125) nor ECM yield (19.2 vs. 17.6 ± 0.92 kg/d; P = 0.097) was different in CRN compared to WHT cows. On day 4 of the heat challenge the mean milk yield was not different in the CRN compared to WHT fed cows (16.3 vs. 14.2 ± 0.95 kg/day; P = 0.086).

Concentrations of protein and lactose in milk were not affected by the heat challenge (P > 0.05), but the milk fat concentration was greater for CRN compared to WHT cows (P < 0.05).

Table 3. Mean daily yields of milk, energy corrected milk (ECM) and milk fat, protein and lactose for cows offered the CRN and WHT diets during the baseline and heat challenge periods.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline</th>
<th></th>
<th></th>
<th></th>
<th>Heat Challenge</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CRN</td>
<td>WHT</td>
<td>SED</td>
<td>P-value</td>
<td>CRN</td>
<td>WHT</td>
<td>SED</td>
</tr>
<tr>
<td>Milk yield (kg/day)</td>
<td>18.2 a  18.2 a  0.56  0.997</td>
<td>17.8 b  16.4 b  0.79  0.125</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECM</td>
<td>19.4</td>
<td>18.5</td>
<td>0.71</td>
<td>0.246</td>
<td>19.2</td>
<td>17.6</td>
<td>0.53</td>
</tr>
<tr>
<td>Fat</td>
<td>0.82</td>
<td>0.76</td>
<td>0.038</td>
<td>0.173</td>
<td>0.83</td>
<td>0.76</td>
<td>0.03</td>
</tr>
<tr>
<td>Protein</td>
<td>0.61 a</td>
<td>0.59 a</td>
<td>0.026</td>
<td>0.384</td>
<td>0.59 a</td>
<td>0.53 b</td>
<td>0.013</td>
</tr>
<tr>
<td>Lactose</td>
<td>0.92 a</td>
<td>0.89 a</td>
<td>0.045</td>
<td>0.468</td>
<td>0.92 a</td>
<td>0.84 a</td>
<td>0.032</td>
</tr>
<tr>
<td>Fat</td>
<td>44.5 a</td>
<td>42.7 a</td>
<td>1.98</td>
<td>0.380</td>
<td>45.8 a</td>
<td>47.3 c</td>
<td>2.39</td>
</tr>
<tr>
<td>Protein</td>
<td>33.8</td>
<td>32.7</td>
<td>1.12</td>
<td>0.406</td>
<td>33.1</td>
<td>33.0</td>
<td>0.95</td>
</tr>
<tr>
<td>Lactose</td>
<td>49.6</td>
<td>49.4</td>
<td>1.17</td>
<td>0.842</td>
<td>51.0</td>
<td>51.6</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Means in the same row followed by different superscripts differ (P < 0.05)

1.11 Core temperature

There was no difference in mean rectal temperature in the CRN vs. WHT cows during the baseline period (38.5 vs. 38.6 ± 0.055°C; P = 0.405) or during the heat challenge period (39.8 vs. 40.0 ± 0.131°C; P = 0.166).

Discussion

Feed intake of dairy cows declined when they were exposed to a four-day heat challenge regardless of diet. However, cows fed corn had a smaller decline in intake than cows fed wheat, confirming our first hypothesis. This was mainly due to differences in the intake of lucerne hay, as there was no difference in cereal grain intake between treatments during heat exposure. The difference in forage consumption may be due to a smaller increase in the temperature of the rumen when corn is ingested compared with wheat because corn is more slowly and less completely
fermented in the rumen (Offner et al. 2003; Orskov, 1986) and ruminal temperature has been identified as a driver of appetite (Bhattacharya and Warner, 1968; Gengler et al. 1970). However, the greater intake of cows fed corn may be due to sub-acute ruminal acidosis in the cows fed wheat. In previous experiments, cows fed corn had greater minimum ruminal pH than cows fed wheat (5.6 v. 5.4, Greenwood et al. 2014; 5.8 v. 5.4 Moate et al. 2018). This difference in pH can be exacerbated by decreased forage intake which often leads to decreased rumination and thus saliva entry to the rumen, in turn decreasing the pH of the ruminal fluid (Vermunt and Tranter 2011). While the mechanism remains unclear, feeding dairy cows corn grain resulted in greater intake during heat exposure.

Changing the concentrate offered to the cows resulted in a difference in forage intake as a proportion of the total dietary intake. During the heat challenge, the CRN cows consumed 1.5 kg DM/day more lucerne hay than the WHT cows. This agrees with previous reports where cows reduced the intake of concentrate by 5% and intake of roughage by 22% as ambient temperature increased from 18 to 30°C (McDowell et al. 1976). Cows fed 75% forage with 25% concentrate showed greater heat energy production than those fed a diet of 25% forage (Reynolds et al. 1991). This could be due to the ruminal fermentation of forages producing more heat when compared with cereal grains (MacRae and Lobely, 1982), cows being offered the grain component in the dairy before the forage, or a combination of the two. Thus, changing the cereal grain that is offered to lactating, heat stressed, cows can alter subsequent forage intake.

The heat challenge resulted in a reduction in milk production was reduced and an increase in rectal temperature of cows. However, milk production and rectal temperature were not influenced by dietary treatment. These results don’t support our second and third hypotheses. The greater intake of forage in CRN compared to WHT cows may account for the numerically greater ECM yield of CRN cows, and may also account for the lack of difference in core temperature between treatments. In contrast to our data, Gonzales-Rivas et al. (2018) showed that lactating cows offered a TMR containing corn grain during a summer period had greater milk production and lower rectal temperature than cows offered a TMR containing wheat grain. Under ambient conditions, Garner et al. (2017) reported that cows fed corn grain had a greater core temperature than those fed wheat grain. The inconsistencies between these reports and ours may be a result of variation in dry matter intake, forage to concentrate ratio, stage of lactation, the intensity and type of heat exposure (acute or chronic) and/or the composition of the diet (TMR or grain plus forage). Additional research is required to understand how changing the type of concentrate offered to cows during hot weather affects milk production and core temperature.

Conclusions

Offering slowly fermenting concentrates to lactating dairy cows may improve overall feed intake, particularly of forage. However, the impact of changing the grain type on the resultant milk production and core body temperature is unclear. Nutritional strategies to maintain feed intake in the dairy cow during heat stress are not well understood but could play an important role in adapting to changing climates. Further studies investigating the core and rumen temperature of dairy cows would be useful to understand the mechanisms controlling feed intake and milk
production responses during periods of heat stress. These results have implications for pasture-based dairy operations where the intake of forage may be impacted by the cereal grain offered.

Acknowledgements

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Sources of phenotypic variation in bulk milk urea concentration in NZ herds

P. R. Beatson\textsuperscript{a}, M. Koot\textsuperscript{a}, N. G. Cullen\textsuperscript{b}
\textsuperscript{a}CRV Ambreed, P O Box 176, Hamilton, New Zealand
\textsuperscript{b}Animal Genomics, AgResearch Limited, Ruakura Agricultural Centre, Private Bag 3123, Hamilton 3240, New Zealand

Short Title: Variation in milk urea levels in NZ herds

Abstract

Between 2013 and 2018, 705,000 milk samples from 190,000 cows in 573 herds were analysed for Milk Urea concentration (MU) mg/dL. The samples were collected through standard herd testing and involved 3,112 herd tests, 2,783 and 329 from spring- and autumn-calving herds, respectively. At each test, mean MU (mMU) was calculated and compared with volume-weighted mean MU (vwmMU) calculated by weighting each cow’s MU by her test day milk volume. mMU across all herds was 29.5 mg/dL and vwmMU was 29.6 mg/dL. It was concluded that MU reported daily to farmers from the bulk milk sample is not different to mMU. Effects of year, herd, region, season of calving (spring or autumn), month of lactation and test day milk volume on vwmMU were investigated and the implications of using bulk milk MU to predict urinary nitrogen excretion discussed.

Key words

Milk urea, urinary nitrogen, dairy cows, variation

Introduction

The environmental impact of New Zealand (NZ) dairy farming is under increasing scrutiny from both the New Zealand public (Gluckman, 2017) and the end consumer. An issue facing the NZ dairy industry is the negative effect that leached nitrogen (N) has on water quality (Selbie et al., 2015). The urine patch contains high concentrations of N and is the main source of N leached: a meta-analysis (Selbie et al., 2015) indicated that, overall, 20% of urinary N (UN) is leached. Strategies to reduce UN are desired as one pathway to reduce deterioration of NZ groundwater and waterways. However, direct measurement of UN is difficult and proxies are required to monitor UN.

Several studies of cows on total mixed ration diets have reported a relationship between Milk Urea concentration (MU, mg/dL) and UN (g/cow/day): UN increases by ~7 g per unit increase in MU (Jonker et al., 1998; Kaufmann and St-Pierre, 2001; Kohn et al., 2002). Although there is large variance between actual and predicted UN for a single MU measurement on a single cow, when means of MU for groups of cows are considered, this variance is substantially reduced: Jonker et al., 1998 estimated that, with 95% confidence, predicted UN could vary by ±33% from actual UN based on an individual MU observation, but when the mean MU of a group of 10 cows is considered this confidence interval is reduced to ±11%.

Herd's comprise many more than 10 cows and each day a representative milk sample is collected from each herd’s milk supply at collection by the milk processing company: this sample is
analysed for protein, fat, lactose, urea and somatic cell content as the basis for payment and reporting to the farmer. Should this bulk MU value be close to the herd’s mean MU (mMU), then, using a MU-UN relationship, bulk MU may be a useful predictor of average per cow daily UN excretion. Further, when combined with cow number, MU would enable estimation of herd UN loading for that day and, if combined with days in milk, grazed area and time off grazing, UN loading for a target time period and per grazed area could be estimated.

Bulk MU could differ from mean MU in herds of mixed breed makeup, should high milk volume cows have higher MU than lower milk volume cows. Beatson et al. (2018) reported that Holstein-Friesian and Jersey cows had MU 30.8 and 28.2 mg/dL, respectively. Arunvypas et al. (2004) reported that in Holstein cows bulk MU and a simulated bulk MU (by weighting each cow’s MU by her test day volume) were equivalent values, and that these were 0.05 mg/dL greater than mean MU. Although sources of phenotypic variation in bulk MU values have not been published for New Zealand herds, inspection of milk test reports indicates a wide range of bulk MU values; the authors are aware of herds that consistently have bulk MU within a range 15-25 mg/dL, while others are consistently 40-50 mg/dL. This study investigated whether there was significant difference between simulated bulk milk MU and mean MU and explored the influences of herd, year, region, month of lactation, spring vs autumn calving, and breed composition of the herd on variation in simulated bulk MU.

Method

The data analysed were from 705,087 individual cow test day records from 570 Spring-calving herds and 63 Autumn-calving herds during lactation years 2012-13 to 2017-18. At each herd test, each cow’s milk volume and concentrations of fat, protein, lactose, urea and somatic cell score were measured using a FOSS MilkOscan FT+ analyser (FOSS, Hilleroed, Denmark). In total there were 3,112 herd tests (Table 1). For each herd test, mean MU (mMU) was calculated. To compare mMU of each tested herd with the equivalent bulk MU for the milkings involved in the test, volume-weighted mean MU (vwmMU) was calculated for each herd test as:

$$(\text{Sum of each cow (MU x Test day volume)} / \text{Sum of each cow (Test day volume)})$$

This vwmMU value mimics the MU reported in the bulk milk reports for the herd. For all herd tests, vwmMU was regressed on mMU. Each herd was categorised to region according to its geographical location. When calving started in the months June, July or August the herd was assigned as spring-calving while herds calving in February, March and April are designated autumn-calving. Lactation years were categorised for spring calving herds according to their year of calving, while autumn calving herds were assigned to the previous year (e.g., for spring-calving herds lactation year 2013 corresponds to lactation 1/06/13 to 31/05/14 while for autumn-calving herds lactation year 2013 is 1/02/14 to 31/01/15).
Breeds of cow were Jersey, Holstein-Friesian and Crossbred. Breed composition for each herd was calculated by averaging across all cows their Jersey component (J0 to J16). Least squares analyses (JMP) determined the significance ($P < 0.05$) of the fixed effects lactation year, region, herd breed composition, season of calving (autumn vs spring), month of lactation and month of year on vwmMU: herd was fitted as a random effect and test day milk volume, milk protein%, milk fat% and milk lactose% were modelled as covariates. The following model was derived:

\[ \text{vwmMU} = \text{Overall mean} + \text{herd (random)} + \text{region} + \text{lactation month*season of calving} + \text{cov(milk yield)} + \text{error}. \]

**Results and Discussion**

**Differences between vwmMU and mMU**

When vwmMU was regressed against mMU for each herd test (Figure 1), the adjusted $R^2$ value was 99.89%. Across all herd tests the difference between vwmMU (29.6 mg/dL) and mMU (29.5 mg/dL) was <0.1 mg/dL. This is similar to the 0.05 mg/dL difference reported by Arunvipas et al. (2004).

Because higher volume cattle tend to have higher MU (Beatson et al, 2018), it is possible in herds of mixed breed that MU measured in bulk milk may be significantly impacted by volume differences between cows and that the bulk MU value may, therefore, differ from the herd’s mMU. Such a variation would diminish the value of bulk MU as a predictor of mMU. Our results indicate that when bulk MU is simulated by weighting each cow’s test day MU by volume, the difference between a herd’s vwmMU and mMU is only 0.08 mg/dL. This difference is negligible and, therefore, bulk MU for NZ herds is a satisfactory approximation of mMU at that herd test for purposes such as using MU to estimate UN excretion per cow for the day of the herd test.

**Variation in vwmMU**

vwmMU across all herd tests was 29.6 ± 8.05 mg/dL and ranged from 7 to 61 mg/dL.

**Region**

vwmMU in Waikato and lower North Island herds was 2.5 mg/dL lower than in South Island and Northland herds. This finding should be treated with caution because there were only 3,112 simulated test day bulk MU records in the data; many more test day records are required to confidently quantify regional differences.

**Season of calving x Month of Lactation**

vwmMU values for spring-calving herds in the first 6 months of lactation were within the range 26-28 mg/dL (figure 2). After 6 months, vwmMU increased in a linear fashion to 38 mg/dL in late lactation. Godden et al. (2001), Arunvipas et al. (2003) and Jilek et al. (2006) all reported that MU was highest around month four of lactation, in studies where cows were fed total mixed ration diets. Carlsson et al. (1995) suggested that lower MU values in early months of lactation could be attributed to the cow’s inability to consume and digest enough feed to meet energy requirements for early lactation milk production, resulting in greater utilisation of dietary N.
vwmMU was more consistent through lactation for autumn-calving herds than for spring calving herds and was generally within the range 27.5 to 32mg/dL. In early lactation (corresponding to late summer-autumn seasons), autumn-calving herds tended to have higher vwmMU than early lactation spring-calving cows (corresponding to late winter-spring seasons), consistent with our hypothesis of greater efficiency of use of dietary N in early lactation. However, the marked increase evident for spring-calving herds in mid-late lactation (late summer-autumn seasons) was not as pronounced for autumn-calving herds (corresponding to spring-early summer seasons). The only lactation months that spring vs autumn-calving herds were statistically different were month 5 (corresponding to a questionable spike in the data for autumn-calving herds) and months 10 and 11. These results indicate there may be an additive effect of season of year and season of calving on MU. Again, further analyses involving more herd bulk MU data are required.

Milk volume

Each one litre increase in test day milk yield increased bulk MU by 0.26mg/dL indicating that high milk yielding cattle have higher MU. When milk volume was fitted, the effect of herd breed composition was statistically not significant. This outcome has practical implications when it comes to comparing MU between herds differing in breed composition: test day volume is reported along with MU and may be used to standardise MU as opposed to using a breed correction, which would require analyses involving additional records of individual cows that could be difficult to access.

Herd

Of the variables tested in the model, herd had the greatest influence on vwmMU, explaining 27% of the variation. Furthermore, repeatability of vwmMU across herd tests (within and across lactations) was 0.35. This indicates that factors intrinsic to herd management tend to affect MU and that these factors need to be explored to determine if these husbandry practices or system-level differences can be manipulated to optimise MU.

Conclusions

Bulk MU, simulated by volume-weighting MU for cows at herd test, is not different to mean MU, thus making bulk MU an accurate indicator of mean MU of each cow in the herd. As such, bulk MU may be a useful predictor of UN excretion per cow in the herd to which the test day bulk sample applies.

Bulk MU is widely variable between herd tests, with the variation influenced by month of lactation or month of year (with these effects possibly being additive), test day milk volume and geographical region. However, these influences are small relative to variation between and within herds from test to test and causes of this variation should be explored to investigate ways in which MU may be managed at the herd level. Analyses of comprehensive bulk milk data held by milk processors would enable more robust quantification of sources of variation in MU.

References


<table>
<thead>
<tr>
<th>Area (code)</th>
<th>Herd tests</th>
<th>Milk samples</th>
<th>Herds</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>South Island (13)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autumn calving</td>
<td>42</td>
<td>3,972</td>
<td>7</td>
</tr>
<tr>
<td>Spring calving</td>
<td>412</td>
<td>146,110</td>
<td>95</td>
</tr>
<tr>
<td>South Island Total</td>
<td>454</td>
<td>150,082</td>
<td>102</td>
</tr>
<tr>
<td><strong>Lower North Island (40)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autumn calving</td>
<td>53</td>
<td>4,813</td>
<td>9</td>
</tr>
<tr>
<td>Spring calving</td>
<td>695</td>
<td>153,300</td>
<td>137</td>
</tr>
<tr>
<td>Lower North Island Total</td>
<td>748</td>
<td>158,113</td>
<td>146</td>
</tr>
<tr>
<td><strong>Waikato (58)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autumn calving</td>
<td>125</td>
<td>12,515</td>
<td>23</td>
</tr>
<tr>
<td>Spring calving</td>
<td>1108</td>
<td>255,688</td>
<td>221</td>
</tr>
<tr>
<td>Waikato Total</td>
<td>1233</td>
<td>268,203</td>
<td>244</td>
</tr>
<tr>
<td><strong>Northland (60)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autumn calving</td>
<td>109</td>
<td>10,091</td>
<td>24</td>
</tr>
<tr>
<td>Spring calving</td>
<td>568</td>
<td>118,598</td>
<td>120</td>
</tr>
<tr>
<td>Northland Total</td>
<td>677</td>
<td>128,689</td>
<td>144</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td>3112</td>
<td>705,087</td>
<td>636</td>
</tr>
</tbody>
</table>

Table 1: Number of herd tests, total milk samples, herds by region and season of calving.

Figure 1: Linear regression between volume-weighted mean milk urea concentration (vwmMU, mg/dL) and mean milk urea concentration (mMU, mg/dL)
Figure 2: vwmMU (mg/dL) by lactation month for spring and autumn calving herds. Horizontal lines at each point depict 95% confidence limits.
Correcting for time dependant drift in ruminal pH sensors

S. R. O. WILLIAMS *, W. J. WALES AND P. J. MOATE

Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia

* Corresponding author. E-mail: richard.williams@ecodev.vic.gov.au

Abstract

Measurements made by electronic sensors may drift over time. We propose the following time-dependent correction equation (1) which allows for an offset at pre-use calibration and drift as detected at post-use validation.

\[
\text{Actual value} = \left\{ (a_0 + b_0 X) \times \left( \frac{1 - \delta}{\Delta} \right) \right\} + \left\{ (a_\Delta + b_\Delta X) \times \left( \frac{\delta}{\Delta} \right) \right\}
\]

(1)

Where \(a_0\) and \(b_0\) are calibration constants at time 0, while \(a_\Delta\) and \(b_\Delta\) are calibration constants at validation time \(\Delta\) (hours after time 0), \(X\) is the variable of interest (for example, ruminal pH) and \(\delta\) is the elapsed duration (h) between time 0 and the time of measurement. The equation was tested on pH data from 328 cow-days. The pH sensors were calibrated in standard solutions (pH 4 and 7) before and after use. Linear calibration equations were created for time 0 and time \(\Delta\) then Equation 1 was used to correct all recorded ruminal pH data. The average (± standard deviation) drift across all sensors at all deployments was -0.06 ± 1.58%/day. A similar approach has been used to successfully correct drift in temperature loggers.

Our equation corrects for errors in sensor data due to initial offset and linear drift over time. It also allows for sensors to be calibrated and validated at convenient times rather than immediately pre and post deployment.

Keywords

- calibration; rumen; sensors

Introduction

Electronic devices to measure ruminal pH have been described by numerous researchers (e.g.: Coleman et al. 2010; Penner et al. 2006) but their measurements can drift with time. Several strategies have been used to manage this drift including frequent calibration (Bevans et al. 2005), limiting the duration of observations (Mullins et al. 2012), and mathematically adjusting the recorded data (Kaur et al. 2010; Palmonari et al. 2010). Published drift correction procedures include adjusting for linear change in pH (Kaur et al. 2010) and linearly apportioning measured drift after physical recovery of the sensor (Palmonari et al. 2010). The drift correction of Palmonari et al. (2010) uses measurement number as the increment and does not include an allowance for an initial discrepancy between the pH as recorded by the sensor and the true pH.
We propose the following novel, time dependent equation (1).

\[
\text{Actual value} = \left\{ \left( a_0 + b_0 X \right) \times \left( 1 - \frac{\delta}{\Delta} \right) \right\} + \left\{ \left( a_\Delta + b_\Delta X \right) \times \left( \frac{\delta}{\Delta} \right) \right\} 
\]

(1)

Where \( a_0 \) and \( b_0 \) are calibration constants at time 0, while \( a_\Delta \) and \( b_\Delta \) are calibration constants at validation time \( \Delta \) (hours after time 0), \( X \) is the variable of interest (for example, pH) and \( \delta \) is the elapsed duration (h) between time 0 and the time of measurement. This equation allows for the possibility of an offset to account for any discrepancy between pH as measured by the intra-ruminal sensor and the pH standard in the period immediately before the intra-ruminal sensor is placed in the rumen. Eqn. (1) also allows for a time dependent, linear drift correction procedure to cover the period from pre-use calibration to post-use validation.

Although it has been reported that pH sensors may drift (Kaur et al. 2019; Palmonari et al. 2010) the extent of this drift has not been well documented. The aim of this research was to measure and document the extent of drift in intra-ruminal pH sensors, present a novel equation that can be used to correct data with respect to this drift, and demonstrate the use of this drift correction process with actual data.

**Materials and methods**

Ruminal pH data from 27 intra-ruminal boluses (KB5; Kahne Limited, Auckland, New Zealand) were collated from three experiments with 10 unique diets (Table 1). The boluses were calibrated before use in solutions of pH 4 and 7. The boluses were then placed in the rumen of rumen fistulated cows where they remained for between 3 and 7 days before being retrieved. Post-use, the boluses were rinsed in cold, clean tap water and were then validated in solutions of pH 4 and 7 by simply recording the measured pH. Linear calibration equations at time 0 and \( \Delta \) were developed based on the calibration and validation results. The calibration slopes (\( b_\Delta \)) at time \( \Delta \) were divided by \( \Delta \) and multiplied by 100 to give the percentage change in calibration slope per day for each bolus at each deployment.

**Table 1: Summary of experiments where pH data were collected.**

1 7 days on 3 different occasions.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Design</th>
<th>Dietary treatments</th>
<th>n</th>
<th>DIM</th>
<th>Measure days</th>
<th>Milk yield</th>
<th>Total DMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russo et al.</td>
<td>Randomised</td>
<td>Lucerne hay, 6 d adapt</td>
<td>7</td>
<td></td>
<td></td>
<td>17.8</td>
<td>18.7</td>
</tr>
<tr>
<td>(2018)</td>
<td>block</td>
<td>Lucerne hay, 11 d adapt</td>
<td>7</td>
<td>235</td>
<td>3</td>
<td>16.5</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ryegrass hay, 6 d adapt</td>
<td>7</td>
<td></td>
<td></td>
<td>13.4</td>
<td>15.5</td>
</tr>
</tbody>
</table>
The boluses were deployed in 31 different, ruminally fistulated, Holstein-Friesian dairy cows and data was collected every five minutes. The 91,600 time-point records were processed with no allowance for sensor drift (RAW) and Eqn. (1) was used to produce drift-corrected data (COR). Processing was done using Excel 2016 (Microsoft Corporation, Redmond, Washington, United States) and resulted in 328 cow-days of summary records for each of RAW and COR. The difference between each RAW and COR record pair was calculated for the mean pH, minimum pH, maximum pH, duration pH less than 6 (h), and the area less than pH 6 (pH.h).

**Results**

Plots of RAW ruminal pH over time showed that drift was linear (Fig. 1, example only).

**Fig. 1:** Example of drift correction of ruminal pH data collected using intra-ruminal boluses.
The daily drift percentage varied between boluses and between deployments (Fig. 2, not all boluses shown). For some sensors, the drift was negative (recorded pH less than actual), while for some the drift was positive, (recorded pH greater than actual). The average (± standard deviation) drift across all sensors at all deployments was -0.06 ± 1.58%/day. Drift ranged from -7.23%/day to +9.72%/day.

**Fig. 2:** Example drift rates of intra-ruminal boluses used to record ruminal pH.

On average, RAW pH data overestimated the daily mean pH, minimum pH and maximum pH, but underestimated the duration pH was less than 6 and the area less than pH 6. However, for individual boluses on separate deployments the differences ranged from large underestimations to large overestimations (Table 2).

**Table 2:** Differences between daily pH statistics when calculated using raw measurements or those corrected for sensor drift. (328 records)

<table>
<thead>
<tr>
<th>pH statistic</th>
<th>Maximum underestimate</th>
<th>Maximum overestimate</th>
<th>Mean¹</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.53</td>
<td>0.83</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>Min</td>
<td>0.73</td>
<td>0.79</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td>Max</td>
<td>0.56</td>
<td>0.92</td>
<td>0.09</td>
<td>0.06</td>
</tr>
</tbody>
</table>

¹ positive values are an overestimate, negative values are an underestimate
Discussion

Our equation (1) corrects for errors in sensor data due to initial offset and linear drift over time. It also allows for sensors to be calibrated and validated at convenient times rather than immediately prior to and immediately post deployment. This is because the adjustment is time based and not reliant on reading number, meaning the scheduling of calibration and validation is accounted for by the equation design rather than needing to be done as the readings immediately pre and post use. As well as reducing the need to limit the duration of deployment of boluses within the rumen (Penner et al. 2006; Mullins et al. 2012), our equation also eliminates the need to calibrate sensors frequently (Bevans et al. 2005; Dohme et al. 2008; Sullivan et al. 2012), and it allows data from sensors identified as having drifted to be used instead of being discarded.

Daily drift was generally small, with some exceptions, but over time the drift can become significant. Thus, if a bolus were to be placed within a rumen for only a day or two, as recommended by Mullins et al. (2012), then drift correction may not be necessary. However, substantial drift may occur in longer deployments, and correction would be required. The marked difference in drift between sensors, and within sensors over deployments, indicates that drift needs to be measured and considered for each individual bolus at every deployment.

Drift in the pH sensors was linear as is shown in Figure 1 where the minimum pH increased from day to day in the RAW data but remained steady in the COR data. This agrees with the observations of other researchers (Kaur et al. 2012; Lohölter et al. 2013; Palmonari et al. 2010).

In practise, our equation can be used as described in the methods, namely; calibrate the sensors and record this time as time 0, deploy the sensors, recover the sensors, validate the sensors and record this time as time Δ. Coefficients are calculated for linear regressions between measured and actual values at times 0 and Δ, then actual values are calculated for every recording using the elapsed duration since calibration (δ).

This research focused on drift in pH data, but we have also successfully used our equation to correct for drift in temperature sensors, which cannot be adjusted to remove the initial offset (KBS; Kahne Limited, Auckland, New Zealand).

Conclusion

Our equation corrects for errors in sensor data due to initial offset and linear drift over time. Daily drift was generally small, with some exceptions, but over time the drift can become significant. We have focussed on correction of drift in pH data, but we have also successfully used our equation to correct for drift in temperature sensors.
Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgements

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References


Whole farm assurance programmes as a means to achieving best management practice dairy farming: A case study of the Synlait Milk Ltd Lead With Pride™ programme

R. J. MacArthur¹,³, A. Renwick¹, K. Old¹ and M. Wren²

¹Lincoln University, Faculty of Agribusiness and Commerce, Ellesmere Junction Road, Lincoln, 7647; ²Synlait Milk Limited, 1028 Heslerton Road, Rakaia, 7783; ³Corresponding author.

Email: ryan_macarthur_@hotmail.com

Abstract

Farm assurance schemes that facilitate best management practices may be viewed as a means by which the dairy industry is able to maintain a social license to operate and facilitate productive and sustainable farming systems. The Synlait Milk Limited Lead With Pride™ (LWP) programme seeks to demonstrate industry leadership by recognising and financially rewarding suppliers who achieve dairy farming best practice. A qualitative study was conducted to understand the adoption motivations and benefits amongst farmers and to determine the financial value returned to suppliers. Thirteen semi-structured interviews were conducted with certified and non-certified suppliers to understand their perceptions and motivations. Three of the participant farms provided data to conduct an analysis of the costs and returns associated with the programme to assess its impact on profitability. The findings indicate that adoption of LWP practices allowed for increased profitability, predominately attributable to changes within animal health and welfare and environmental practices. The qualitative research identified perceived relative advantage, compatibility and complexity as the dominant factors influencing supplier’s behaviour regarding adoption. Respondents gave weight to premium offerings, industry developments and importance of support from extension services, in achieving certification. Findings from the research provide evidence that adoption of whole farm assurance scheme within intensive farming operations can drive profitability, provide farm practice advantages and ensure sustainability within our primary industries.

Keywords

farm assurance scheme, dairy, financial

Introduction
Whilst New Zealand’s dairy sector growth has driven economic returns, it has been reliant upon increases in production and subsequent changes to farming practices, primarily intensification, to meet market demand and maximise returns. Globally, concerns extend to the treatment of animals, environmental impacts of production, food safety concerns, and social implications of production methods which affect the utility or wellbeing of third parties, such as the public (Olynk and Ortega 2013). Farm assurance schemes (FAS) are a means by which the concerns of biophysical effects of dairy intensification may be addressed. FAS encompass the principles of quality assurance and apply them at the farm level through programmes which operate throughout the entire supply chain (Manning et al. 2006). FAS are initiatives that “provide primary production standards for food safety and other characteristics that are of relevant importance to consumers” (Lewis et al. 2008 p. 1089). Best management practices (BMPs) commonly underpin FAS and have been developed in recognition of the complex challenges of land management and water resources for addressing sustainable intensification of agriculture (Shiferaw et al. 2009). BMPs are incorporated within the standards for which certification may be audited against (Wood et al. 1998).

Insight into the motivations and perceived risks of farmers is required in the design of FAS to tailor and bundle incentives for maximum effectiveness and efficiency (Greiner et al. 2009). For socially motivated farmers, recognition by their peers and the community can be an equally powerful adoption incentive (Greiner et al. 2009). A sense pride in their production practices and a desire to achieve high levels of production are influencing factors for adoption (Jay 2007). Adoption of practices through FAS may also be influenced by financial factors, farm characteristics, demographic factors and psychological factors (Serra et al. 2004; Menozzi 2015; Small et al. 2016). Offering financial incentives for farms adhering to BMPs may also assist in uptake of FAS (Blackman and Rivera 2010).

Method

The research undertook a case study of Synlait Milks Lead With Pride™ (LWP) programme. Case studies are considered useful for preliminary and exploratory research (Rowley 2002). LWP seeks to demonstrate industry leadership by recognising and financially rewarding suppliers who achieve dairy farming best practice. The whole FAS follows a four-pillar approach, focusing on environment, animal health and welfare (AHW), milk quality (MQ) and social responsibility (SR). The programme is an independently audited ISO/IEC 17065 accredited programme and for achieving certification suppliers are rewarded with a $0.06/kgMS premium.

FAS Adoption

Thirteen farms (10 certified and 3 non-certified) were selected to participate in semi-structured interviews to understand their perceptions and motivations. Participants were selected using theoretical sampling (Eisenhardt 1989) upon their extremes of involvement within the programme, with an even split of those exhibiting high and low levels of engagement. The theoretical model of adoption behavior was adapted from Reimer et al. (2012) and utilised to inform this study (Fig. 1). It incorporates the diffusion of innovation theory (Rogers 1995) within the influence upon perceived practice characteristics and beliefs on behavioural change. It provides a
useful framework for guiding the factors that influence the behaviour of FAS adoption and incorporates factors that highlight programme advantages and disadvantages.

Fig. 1 LWP adoption framework (Reimer et al. 2012, p. 119)

Interviews conducted in August 2017, were transcribed, coded and interpreted using inductive analysis methods to help identify themes among the research participants (Turner 2010). Thematic analysis was utilised to distinguish patterns that occurred throughout the data (Schreier 2012). Qualitative content analysis determined the significance of a given theme, which gave recognition to both the key themes expressed by interview participants and the frequency they were mentioned, both by an individual and the interview population (Schreier 2012). The content analysis adopted a mixed inductive and deductive approach. Deductive categories were constructed from the Reimer et al. (2012) model to allow categorisation of concepts.

Financial evaluation

Requirements were first classified as either mandatory, quantifiable or non-quantifiable. Mandatory requirements were those required of suppliers regardless of participation in LWP and were excluded from the financial evaluation. Quantifiable requirements were those which were quantifiable and had an associated measurable parameter as a direct result of a programme requirement. These were the focus of the financial evaluation. Non-quantifiable requirements were those which had no associated measurable parameter and weren’t included within the financial evaluation. Wossink and Osmond (2002) model was utilised to perform the financial analysis. This model adopts the net present value method to assess the net profitability of BMP. Prices were calculated for quantifiable requirements with the cost of a practice subtracted from the increases in revenue. The change in return added to the LWP premium of $0.06/kgMS provided a net addition to the annual profitability of the farm. Where possible, records from three participant farms were obtained to ensure actual data of the measurable parameters accurately reflected the economic effect of LWP. Where farms had no records of quantifiable requirements, industry data and scientific
literature was utilised. The 2016/2017 season milk price of $6.30\textsuperscript{a} was used for any milk production related calculations. Major capital expenditure was excluded, including requirements to change irrigation or changes to effluent systems. Suppliers recognised that these investments were required due to compliance or operational.

**Results and Discussion**

Behavioral beliefs were the overwhelming influence in the decision to adopt LWP predominately driven by factors of relative advantage, compatibility with farm systems, observability and complexity. Elements of these factors also influenced the normative and control beliefs which are discussed below.

*Relative Advantage.* Individual’s belief attitudes towards LWP adoption was influenced by the extent they perceived there to be a relative advantage in participating, with more perceived advantages increasing the likelihood of adoption. The main influences upon relative advantage included premium payments, accountability, record keeping and proactiveness to industry changes and compliance. The strong influence of relative advantage in a supplier’s decision to adopt LWP is strengthened by the fact that the other perceived practice characteristics from the model can influence it. For example, complexity may reduce a given innovations relative advantage through increasing the intensity of the effort required, creating a disadvantage and decreasing adoption (Pannell et al. 2006).

*Compatibility.* The SR pillar of LWP was identified as requiring the most change in practices on farm. The influence of these aspects of farming have largely been overlooked, given the production focused nature of the dairy industry (Clark et al. 2007). This struggle negatively impacted upon supplier’s behavioural beliefs and decision to adopt LWP as they had to alter their farm systems with unfamiliar practices. However compatibility could also positively influence behavioural beliefs, allowing farms to choose to apply new practices that enhanced their operation, helping to improve adoption rates.

*Observability.* Farmers are interested in the development of strategies for constructing alternative supply chains, which recognise management practices and provide increased value from their commodities (Higgins et al. 2008). Suppliers identified the development of a product linked to LWP, as having the potential to create opportunities allowing market premiums for changes in production practices. Utilising this concept to increase adoption is a difficulty because the production practices of LWP are largely credence attributes, which cannot be detected by the consumer during consumption and are therefore difficult to market (Northen 2001). Suppliers expressed a desire for their practices and willingness to conform to public demands, to be better understood. This suggested that observability influenced suppliers’ normative beliefs, and that adoption could be motivated by the ability of the program to be observed by the public and practice outcomes more widely understood. FAS can assist in improving the public’s perception of farm operations and are a leading solution in alleviating public concerns through more proactive management and stewardship practices (Atari et al. 2009).

\textsuperscript{a}$6.30 was the average 2016/2017 season payout. This included a base payout rate of $6.16 and an additional average incentive and premium of $0.14.
Complexity. Suppliers identified that their inclusion within the Standards Committee (who review and consider the development of new standards) was integral to them having a say on direction of the programme and ensuring its requirements remained practical and simplistic behind the farmgate. This impacted upon the control beliefs of suppliers, with those whom had participated, finding it improved their attitudes relating to adoption as they felt a sense of influence. The involvement of participants in the development process ensures an interaction between the scheme development and the formation of attitudes of those relevant to the scheme (Falconer 2000).

The financial analysis calculated an achievable profit increase. This was obtained through the environmental, AHW and MQ pillars. There were no quantifiable returns in the SR pillar. The study identified a reasonable capital expenditure outset was required to meet certification requirements, however this was easily recoverable through the first year of certification. The financial viability of FAS adoption is important as it has the potential to highlight win-win situations, where production practice benefits can occur simultaneously alongside productivity and economic benefits (Main et al. 2014).

The environmental pillar included the most significant capital cost requirements. Offsetting impacts, meeting BMPs and compliance with regards to environmental factors requires high levels of investment and capital infrastructure (Macdonald 2014). The largest environmental benefit came from savings relating to the GPS precision spreading of fertilisers. A significant economic benefit is expected in this area due to fertiliser inputs being the single largest annual farm expenditure item (Yule and Lawrence 2007). Analysis of Synlait milk data showed reduced grading instances amongst LWP suppliers, which beyond the grade free incentive, was the main benefit of the MQ pillar. Suppliers credited the establishment of systems and procedures in reducing instances of milk grading. Reductions in grading instances requires the application of education, knowledge transfer and motivation to achieve control and improvements (Green et al., 2007 as cited in More 2009). Offering premiums for producing high quality milk has a strong effect on the overall MQ achieved (Nightingale et al. 2008). AHW benefits were mainly attributable to reduced culling from mastitis and achieving heifer liveweight targets. It is widely recognised that culling due to mastitis is a large factor causing economic losses in dairy systems (Huijps et al. 2008). Heifers found to be below target live weights can have extended calving patterns leading in to their first lactation resulting in economic impacts from fewer days in in milk and issues through subsequent matings (Penno 1997; Brownlie et al. 2014). FAS provide frameworks allowing for thorough review and ensures a detailed focus on known factors of BMP to enhance performance and profitability of dairy enterprises.

Conclusion

This qualitative study focused on understanding adoption of LWP, indicated that consideration of the advantages from programme participation was the most influential factor upon adoption. This suggests that more focus on the communication of advantages of FAS will assist in driving adoption amongst farmers. A financial evaluation concluded that implementation of FAS can be profitable for farming enterprises with economic advantages particularly in AHW and environmental practices. Considering adoption drivers and communicating economic benefit in the
development and delivery of FAS positions them favourably when addressing issues from dairy intensification in New Zealand.

**Acknowledgements**

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**Conflicts of Interest**

Mark Wren is Lead With Pride™ Manager at Synlait Milk Ltd.

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Reducing nitrate leaching from the urine patch – a plant based approach

H.G Judson¹, A.J.E Moorhead¹ P.M Fraser², M Peterson² P.D Kemp² G.R Edwards⁴

¹ Agricom, P.O Box 3761, Christchurch
² Plant & Food Research Lincoln Private Bag 4704 Christchurch Mail Centre, 8140
³ School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
⁴ Agriculture and Life Sciences Faculty, Lincoln University, P.O. Box 84, Lincoln University,

Abstract

Reducing nitrate leaching from urine patches created in intensive grazing systems is becoming important with the aim of improving water quality. Genotypes of Plantago lanceolata offer a plant-based solution for reducing nitrate leaching from the urine patch by reducing the nitrogen load in the urine patch and by reducing the speed of nitrification in the soil, although not all plantain cultivars are effective. Including plantain in the forage base does not appear to adversely affect either pasture DM production or milk solids production of dairy based production systems.

Key words

Plantago lanceolata, plantain, nitrogen nitrate leaching, nitrification, urine patch, intensive grazing systems

Introduction

Regional councils in New Zealand are placing restrictions on nitrate leaching losses from agricultural land with the aim of improving water quality in rivers and lakes. The predominant source of nitrate leaching in a grazing system is the urine patch, with up to 90% of the nitrogen (N) leached to ground water in a livestock system coming from this area of high N load (Ledgard et al., 2009). Therefore, management options that reduce the N losses in the urine and/or from the urine patch will have a significant impact on N leaching.

Plantago lanceolata (Plantain) (largely cv Tonic) commercialised in New Zealand over 25 years ago (Stewart 1992), has become a successful forage plant for livestock particularly sheep, beef cattle and deer. Plantain pastures provide benefits during lactation for ewes through improved intake, reduced faecal egg output (Judson et al. 2009) and increased milk production (Kenyon et al. 2010), and also for lamb finishing (Moorhead et al. 2002; Kemp et al. 2013) through improved liveweight gain (relative to perennial ryegrass pastures). Recently, “diverse” pastures containing ryegrass, clovers and forage herbs, including plantain have been shown to reduce urinary nitrogen concentration in dairy cows (Totty et al. 2013). Initially, this focus was on diversity per se rather than specific components of the pasture however, further work in diverse pastures at the species level (Box et al. 2016) has shown a more specific role for plantain in reducing the environmental impact of dairy farming.

Functional plantain is now recognised as a powerful tool to reduce urinary N concentration (Box et al. 2016, Cheng et al. 2017) and slower nitrification (Judson et al. in press) and thus loss of nitrogen from the urine patch through the soil profile (Woods, 2017; Carlton et al. 2018; Navarrete et al. 2018).

The aim of this paper is to present the evidence for the mechanisms through which an environmentally functional plantain (now commercially represented by the brand Ecotain) reduces nitrate leaching from the urine patch.

Plantain as a species is largely a winter dormant flat weed while the domesticated and cultivated forms range from late heading winter dormant types to upright winter active forage plants. For clarity,
Plantain in this paper refers to winter active, upright and productive forage plantains (almost exclusively cv Tonic or Agritonic), and this paper will demonstrate not all plantain cultivars are equally effective in reducing N leaching.

Plantain cultivars which are the most environmentally functional reduce nitrate leaching using four mechanisms. Two of these are within the animals affecting total N output and urinary nitrogen concentration and two within the soil through biological nitrification inhibitors originating from the urine and from plant material. Evidence for these mechanisms are presented below.

**Urinary N output**

The amount of N excreted in urine is proportional to the amount of N consumed in the diet but typically 50% of dietary N is excreted in urine (Luo & Kelliher 2010). Reducing N intake is therefore a powerful tool in reducing urinary N excretion, although for pasture-based diets the ability to control N intake is often limited or requires specialist supplementation. The relationships between N intake and urine excretion has been generated largely from ryegrass/white clover diets (Luo & Kelliher 2010). Previously, alternative forages have demonstrated their ability to alter N partitioning, reducing the N excreted in urine at a given N intake. For example, *Lotus corniculatus* has been shown to reduce N excretion in urine from 49% (ryegrass control) to 34% (45% lotus diet) in late lactation dairy cows despite similar N intake (500g N/cow/day) (Woodward et al. 2009). Similarly, for plantain there is some evidence for the partitioning of N away from urine by cattle grazing plantain (Nkomboni, 2017, Navarrete et al. 2016, Cheng et al. 2017). For example, Cheng et al. 2017 reported less dietary N excreted in urine from young dairy cattle fed plantain diets (41g – 33% of dietary N) compared with ryegrass diets (65g – 54% of dietary N) despite similar N intake (approximately 120g N/day). The *in vitro* fermentation experiments of Navarrete et al. 2016 offers some possible explanation with significantly lower ammonia production from diets enriched with two secondary plant compounds (aucubin and verbascoside) present in plantain.

**Urinary N concentration**

Livestock grazing plantain typically have a much lower concentration of urinary nitrogen, determined from spot samples following milking, than livestock grazing ryegrass/white clover pastures despite similar N intakes (Box et al. 2016, Cheng et al. 2017 Nkomboni 2017). For example, Cheng et al. (2017) reported urinary N concentrations less than half (0.35 vs 014%) for young dairy cattle consuming plantain than for those on ryegrass. Lower urinary N concentration is an obvious consequence of a reduced dietary N partitioned to urine (as outlined above) but is also a function of increased urine volume. The urine patch N loading rate is a key metric for quantifying and modeling the fate of N and urinary N concentration is an important factor in determining nitrate leaching (Selbie et al. 2015).

Increased urine volume in livestock fed plantain may be a consequence of two mechanisms. First, the response to the presence of a diuretic (O'Connell et al. 2016) and second increases in water intake as a consequence of a typically lower dry matter content compared to perennial ryegrass (Cheng et al. 2017). Reductions in the amount of dietary N escaping to urine are related to the presence of verbascoside (Navarrete et al. 2016)

It is noteworthy that not all plantain cultivars and breeding lines appear to display the same potency of diuresis (Figure 1.) In a recent study, (Judson et al. 2018 in press) Romney ewes lambs (5 months old) were offered either perennial ryegrass or a range of plantain cultivars or plantain breeding lines at DM intakes to achieve an equal feed water intake of 5.5l. Drinking water was withheld. There were significant differences (Fisher’s LSD) in urine volume collected over 72 hours from lambs in metabolism crates. Commercial lines (n=6) were not different to grass, but breeding lines (n=4) and
“Ecotains” (n=2) produced significantly more urine despite a similar water intake. Breeding lines and Ecotains share a common breeding pool suggesting this functionality is heritable.

![Figure 1](image.png)

**Figure 1.** Urine volume (mL) from ewe lambs fed plantain genotypes; commercial lines (6) breeding lines (4) and Ecotain (2) and ryegrass balanced for water intake. Letters represent significant differences between the means. From Judson et al. in press

**Biological nitrification inhibitors in urine**

Nitrification refers to the conversion of soil ammonium through to nitrate. It has been shown that ammonium oxidising bacteria (AOB) are the main drivers of nitrification in soils, with the activity of AOB increasing 177-fold after the application of an ammonia substrate (Di *et al.* 2009). Reducing the rate at which this process happens has the potential to reduce nitrate leaching by allowing pasture plants in the urine patch a longer period of time to take up the available nitrogen before more is converted to the readily leachable nitrate form as this increases its potential for loss.

Data from sheep studies (Judson *et al.* 2018 *in press*) indicate urine from animals fed plantain behaves differently when applied to soil. Urine was collected from lambs that had grazed either perennial ryegrass or plantain for 14 days prior. Ryegrass urine was diluted with water to achieve the same nitrogen concentration as the plantain urine (802 mg N/kg) and each urine was applied separately to soil microcosms (70 mL plastic vials containing 20 g of air-dried Templeton loam soil). Replicates of each treatment (plantain or perennial ryegrass urine) were destructively sampled over time to determine the net nitrification rate. For urine from ryegrass fed lambs, nitrate accumulated quickly, such that at 21 days post-application, almost 50% of available urinary N had been converted to nitrate via the process of nitrification. (Figure 2). The urine from lambs fed plantain had a much slower nitrification rate overall and especially in the first 28 days post-application where a significantly lower proportion of the urinary N was converted to nitrate.
Figure 2. Cumulative amounts of nitrate produced (mg/kg soil) in urine equalised to a nitrogen concentration of 802mg N/kg from Agritonic and ryegrass-fed sheep during the soil incubation over time. Bar represents the LSD5%.

Biological nitrification inhibitors in the sward

Soil incubation experiments have shown inhibition of nitrification when aucubin was incorporated into soil (Deitz et al., 2012). Further, nitrification activities were shown to be low and nitrifying bacteria reduced 200 fold in the presence of plantain plants when given access to ammonium fertiliser (not urine) (Verhagen et al., 1995). These authors provided an alternative possible mode of action suggesting plantain was simply more competitive than nitrifying bacteria for limited NH$_4$ concentrations rather than the involvement of secondary plant compounds. Woods (2017) and Carlton et al. (2018) also recorded reductions in the abundance of ammonia oxidizing bacteria in soils containing plantain.

Systems effects

Lysimeter studies are an excellent way of looking at the effect of the various mechanisms working together. Woods (2017) recorded a 45% reduction in N leaching when urine from ryegrass fed dairy cows was applied to Italian ryegrass swards containing 42% plantain on a DM basis. Further, when urine derived from dairy cows grazing swards containing plantain (42%) was applied to Italian ryegrass swards containing 42% plantain on a DM basis, the reduction was 89% compared to normal urine on ryegrass swards. In similar work, Carlton et al. (2018) demonstrated a 74% reduction in nitrate leaching using swards containing plantain. These swards contained only 20-30% plantain suggesting maximising the plantain content in the sward may not optimise the reduction in N leaching. Having sufficient ryegrass present to act as a nitrate “mop” may be more important than maximizing the amount of plantain in the sward botanical composition. Traditionally plantain has been sown as a third order pasture species at 1-
2kg/ha. However, the new use of this species as a tool to mitigate nitrate leaching will require increases in sowing rate to achieve the desired sward content for the longest period of time possible.

Work at Massey University has begun assessing leaching losses from hydrologically isolated paddocks (Navarrete et al. 2018). This facility allows the collection of leachate from large areas of either ryegrass, plantain or plantain/clover mixtures under grazing by dairy cows. This is a useful “proof of concept” measuring loss rather than estimating from a model of farm system components. Early indications (Navarrete et al. 2018) suggest reductions in nitrate leaching of around 50% from pure plantain on a paddock scale are possible which is similar to those reported from lysimeters (Woods 2017; Carlton et al. 2018).

**Dry matter production**

Annual and seasonal dry matter (DM) production are key component of pasture-based production systems affecting milk production (Holmes et al. 2007) and profitability.

The effect on DM production of incorporating plantain into pasture mixes is variable depending on the environment and season. In an environment which support excellent pasture production, Minee et al 2013 reported excellent but lower average production over 2 years from plantain (17.5tDM/ha per year) than for ryegrass (19t DM/ha per year). However, other environments where annual yields of ryegrass are around 12 t DM/ha, plantain stands have been more productive (17t DM) (Powell et al. 2007). In a 3 year evaluation of Northland pastures, Moorhead and Piggot (2009) found increased production in kikuyu pastures containing plantain, typically in the summer and autumn periods. These studies generally indicate that where pasture DM production is high plantain DM production will be similar. However, in more challenging environments plantain may improve total DM production (Martin et al. 2017).

**Milk Production**

Typically, milk production from cows on plantain diets have been similar to those on ryegrass, sometimes higher but never less. For example, cows produced similar amounts of milk in early lactation and more in late lactation in a study of ryegrass and plantain diets (Box et al. 2017) and in 1 of 2 weeks in summer (Minnéé et al. 2017). Further, Minnéé et al. 2012) noted that plantain had the ability to improve milk solids production when included in the diet in summer/autumn with increases in nutritive value and dry matter intake being likely causes. Only minor changes in milk composition have been observed (Minnéé et al. 2017, Box et al. 2017)

**Summary**

Regulations restricting the amount of nitrate leached from farmland are becoming an important consideration of livestock farming. Up to 90% of nitrate leached from farms comes from the urine patch.

Plantains cultivars which are fully functional are a powerful tool in reducing nitrate leaching using four mechanisms to reduce the N-loading of the urine patch and slow the nitrification rate in the soil.

There are significant differences between plantain genetics in their ability to influence nitrate leaching in each of the four mechanisms presented with the majority of current work focused on one genetic pool. Typically, both forage dry matter production and milk production are similar to but never lower than ryegrass systems for this specific plantain material indicating there is unlikely to be a penalty to production from including it in a pasture base system.
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Economic implications of altering irrigation scheduling

Carla Muller\textsuperscript{1}, Mark Neal\textsuperscript{2}, MS Srinivasan\textsuperscript{1} and Richard Measures\textsuperscript{1}

\textsuperscript{1}National Institute of Water and Atmospheric Research Limited
\textsuperscript{2}DairyNZ

Abstract

This research forms a part of the New Zealand government-funded Irrigation Insight programme, which aims to maximise the economic benefits of irrigation through improved irrigation scheduling decisions. We developed a desktop model to estimate the environmental and economic impacts of various irrigation scheduling practices. The model simulates soil water balance and pasture growth rates on a daily timestep. Scenario modelling was used to investigate the average annual direct and indirect economic benefits and costs of irrigation scheduling decisions over an 18-year period. The impacts of altering the irrigation infrastructure, particularly irrigation application depth and frequency, were also examined. Direct costs include irrigator maintenance, labour and pumping costs. Indirect costs include changes in pasture growth as a result of water stress, over-watering, as well as wastage and pugging due to soil moisture levels. Results for a case study dairy farm in Rangiora, South Island, New Zealand, demonstrate that on average, there are significant annual economic (+$830/ha) and environmental (226 mm drainage) benefits if irrigation is scheduled based on soil moisture demand rather than following a set frequency (roster). However, for the case study farm, there is not a significant annual economic (+$25/ha) or environmental (79 mm drainage) benefit associated with changing irrigation infrastructure (purchasing an extra irrigation gun) to enable decrease application depths and rotation lengths (35 mm every 9 days rather than 45 mm every 11 days).

Introduction

In New Zealand, as irrigated dairying expanded over the past decade (Corong, Hensen and Journeaux, 2014), there has been concerted effort to improve irrigation application and scheduling practices (IrrigationNZ, 2015). More efficient spray irrigation methods are rapidly replacing less efficient border-dyke systems (Dark, KC and Kashima, 2017). However, further savings are likely to be gained from improved consideration of economic, soil and weather conditions, particularly linking irrigation scheduling to economic and environmental implications. One of the studies that does consider economic impact of marginal irrigation is one by Foundation for Arable Research (2008). Based on data from five farms, this study concluded that the average capital and operating cost of irrigation was $2/mm.ha, though the study included cost components that do not vary with use, e.g. insurance, and did not include changes in pasture or crop growth.

This paper presents an example application of a new hydrological and economic (hydro-econ) model, designed to look at the relative economic and environmental performance for various irrigation scheduling options. It provides the ability to test scenarios such as alternative return periods (irrigation frequency) and application depths. It focuses on operational costs and benefits and excludes capital costs.

Methodology

Within the hydro-econ model, the hydrological model computes changes in root zone (top 40 cm of soil) soil moisture each day using a water balance approach accounting for rainfall, irrigation, evapotranspiration and drainage (Srinivasan et al., in preparation). The model can vary irrigation
frequency and depth based either on soil storage or by applying a pre-set depth at a pre-set frequency irrespective of soil moisture conditions.

The hydro-econ model was applied to a commercial dairy farm (“Farm A”) located near Rangiora, New Zealand. Eighteen years of daily climate data obtained from NIWA’s Rangiora weather station (NIWA, 2018), approximately 5 km from Farm A, were used in the model. This is a case study and may not be indicative of other farms. Farm A is a dairy farm of 119 effective hectares, all of which are irrigated. It has two main soil types, both with the same field capacity (FC) (123 mm within the root zone).

For each day the economic implications of the soil moisture are captured. Direct costs include the cash costs incurred for irrigating. Four direct costs were included as part of this model:

- **Pumping cost**, in dollars per m$^3$ of water, is a variable cost incurred from moving water from the farmgate to root zone. Based on Farm A’s historic water use and power costs, this was estimated to be $0.04/m$^3$.

- **Repairs and maintenance (R&M) costs**, in dollars per day of irrigation, are the variable costs associated with repairing and maintaining the irrigation system, including replacing pipes and nozzles. For Farm A, R&M costs were estimated to be $286 per day of irrigation, based on their historic water use and farm accounts.

- **Labour costs**, in dollars per day of irrigation, are based on the hourly wage rate for scheduling and moving the irrigator, and account for the skill level of the person undertaking the work. Farm A spent approximately $87 per day on labour associated with irrigation.

The base pasture growth rates, $PGR_{base}$, were based on **DairyNZ Facts & Figures** (DairyNZ, 2017), for the closest measurement location, and while this is likely to underestimate PGRs under perfect irrigation, it provides a proxy to test this model, and these can be altered if better information becomes available. The economic value of pasture is derived from the Forage Value Index (DairyNZ, 2018b), for the Upper South Island, and ranges from $0.13 to $0.42/kgDM depending on the month, these can be changed in the model if there is better information for the farm. Pasture value is calculated based on the final daily PGR multiplied by the economic value of pasture. Indirect costs considered in this study are changes in pasture growth and wastage due to soil moisture levels and reduction in pasture growth from pugging.

- **Soil moisture**, expressed as plant available water (PAW), impacts the daily PGR. In our model we calculate a scaling factor, $F_{moisture}$, accounting for the effect of soil moisture on $PGR_{base}$, as shown in Equation 1. Pasture growth is assumed to be zero when soil moisture is at or below wilting point, WP. While WP varies with soil type, 20% field capacity (FC) was considered a reasonable generalisation (IrrigationNZ, 2018). When soil moisture is greater than the WP and less than the FC, pasture growth rate is reduced according to the ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET) (Doorenbos and Kassam, 1979). This has the effect of reducing pasture growth when soil moisture falls below a threshold ‘wilt point’ (WP) of 50% FC. This threshold can be altered as necessary. Above this threshold pasture growth is not limited by moisture (i.e. AET = PET so $F_{moisture} = 1$). Soil is considered ‘wet’ when PAW is at or above FC. The impact of wet soil on PGR is based on DairyMod and the SGS Pasture model described in Johnson (2016). Johnson (2016) assumes that $F_{moisture}$ at field capacity is 100%, and linearly decreases to 50% at saturation point (Sat). Based on the hydrological model used, saturation is assumed to be 120% FC, a point when slow drainage (i.e. drainage through soil matrix) swaps to fast drainage (i.e. overland flow) in the hydrological model.
\[
F_{\text{moisture}} = \begin{cases} 
0, & \text{if } PAW \leq WP \\
\frac{AET}{PET}, & \text{if } WP < PAW \leq FC \\
\left(0.5 + 0.5 \frac{Sat-PAW}{Sat-FC}\right), & \text{if } FC < PAW 
\end{cases} \quad \text{Equation 1:}
\]

- **Pasture wastage** represents poor utilisation, and increases, in part, with increasing soil moisture which in turn is affected by irrigation scheduling. Causley (unpublished, cited in Beukes et al., 2013) states that pasture wastage increases linearly up to FC, at which point losses average 16%, and losses continued to increase once soil moisture was above FC. Although wastage impacts pasture utilised, rather than growth per se, in order to aggregate the costs and benefits of irrigation, we treat it as an effect on growth. Based on this and the relationships in Causley (unpublished, cited in Beukes et al., 2013), the hydro-econ model assumed that there was no wastage effect on the PGR at WP, and a 16% reduction in PGR at FC. This linear relationship was extrapolated for soil moisture exceeding FC which resulted in a 22.4% decrease in PGR for soils at Sat (Equation 2).

\[
F_{\text{wastage}} = \begin{cases} 
1, & \text{if } PAW \leq WP \\
1 - 0.16 \frac{PAW-SP}{FC-SP}, & \text{if } PAW > WP 
\end{cases} \quad \text{Equation 2:}
\]

- **Pugging** is influenced, in part, by soil moisture levels, and pugging can have a significant impact on pasture growth (Betteridge et al., 2003). In our model, the effect of pugging was only considered when soils are at or above FC for at least three consecutive days. The severity of pugging is determined based on Betteridge et al. (2003), who developed severity curves built on the relationship between stock density (stocking rate and rotation length) and grazing duration, which are determined at a monthly level. The time taken for the pugging damage to recover can be varied, but for Farm A was assumed to be 30 days. Pugging is a compounding effect, with multiple pugging events causing a more significant impact. Based on Betteridge et al. (2003) the impact of pugging was calculated according to Equation 3.

\[
F_{\text{pugging}} = \left(1 - \frac{\text{DaysPugging}}{\text{RotationLength}} \times \text{ImpactSeverity}\right) \quad \text{Equation 3:}
\]

Where: DaysPugging is the number of days in the last 30 days when PAW has been greater than FC for three consecutive days, RotationLength is the stock rotation period in days, and ImpactSeverity is calculated according to Betteridge et al. (2003), taking into account grazing duration and stocking density. If stocking density is zero, then no pugging will occur. For Farm A, ImpactSeverity varied from 0% for June and July when there was no stock, to 56% in May when stocking density was highest.

Utilised pasture growth, PGR\text{revised}, accounting for reductions in growth rate due to moisture, wastage and/or pugging is calculated according to Equation 4. Given that the PGR\text{revised} is scaled relative to a PGR\text{base}, which is a proxy for perfect irrigation, all three factors in Equation 4 (F\text{moisture}, F\text{wastage} and F\text{pugging}) are between 0 and 1.

\[
PGR_{\text{revised}} = PGR_{\text{base}} \times F_{\text{moisture}} \times F_{\text{wastage}} \times F_{\text{pugging}} \quad \text{Equation 4:}
\]

This hydro-econ model allows selection of various irrigation scheduling decisions. This paper focuses on demonstrating the impact of some of the key inputs. Other applications, such as the use of
forecasting, will be the subject of further research. The inputs varied in this paper are summarised in Table 1.

Table 1: Hydro-econ model irrigation scheduling variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Measurement</th>
<th>How often variable is set in the model</th>
<th>Potential options if applicable / notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth per irrigation</td>
<td>mm/day</td>
<td>Monthly</td>
<td>Zero indicates when no irrigation is applied in that month</td>
</tr>
<tr>
<td>Irrigation approach</td>
<td>Selected option</td>
<td>Once</td>
<td>Just in time: Irrigate when soil storage reaches user set threshold</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Always: Irrigate whenever water is available</td>
</tr>
<tr>
<td>Frequency limitation</td>
<td>Selected option</td>
<td>Once</td>
<td>No limit: irrigate whenever it is desired</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum return interval: Cannot irrigate until a set number of days after the last irrigation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Roster: Can only irrigate on pre-set days</td>
</tr>
<tr>
<td>Roster/minimum return period of irrigator</td>
<td>Days</td>
<td>Monthly</td>
<td>Only used if frequency limitation logic is designated roster</td>
</tr>
</tbody>
</table>

This paper presents the results for Farm A, in particular, the economic impact if they maintain their current irrigation infrastructure system, or if they include another irrigation gun and reduce application depth and rotation length. These two options are varied by irrigation approach (just in time or always) and frequency limitation (minimum return interval or roster), see definitions of these in Table 1. ‘Just in time’ irrigation approaches check whether the soil moisture levels are below a pre-defined threshold, before checking if the rostered irrigation is available, if both of these conditions are met irrigation is applied. Conversely, if the ‘always’ irrigation approach is selected the model only checks to see if the rostered irrigation is available regardless of the soil moisture levels across a pre-defined irrigation season. ‘Rostered’ and ‘minimum return interval’ frequency limitations represent different types of water supply and infrastructure constraints. Rostered irrigation represents a supply constraint whereby water is only available every so many days. For example, with an 11-day roster water is available on every 11th day and availability is not influenced by whether or not irrigation actually takes place. A minimum return interval limitation represents an infrastructure limitation whereby it takes several days to apply a single application (typically due to the need to move a limited number of mobile irrigators from field to field in rotation). Minimum return interval limitations mean that irrigation cannot be repeated within a set number of days. For example, with a minimum return interval of 11 days, if irrigation occurs on a given day it is not possible to apply more irrigation for the next 10 days.

Farm A is currently using two irrigation guns, applying 45mm irrigation depth with a return interval of 11 days, they have a minimum return interval and use a just in time irrigation approach. Scenarios with two guns received 45 mm per application and had an 11-day rotation length, scenarios with 3 guns, had an application depth of 35 mm per application and a nine-day rotation length.
Results

All results are the average across 18 seasons. Based on 18 irrigation seasons, Farm A on average receives 217mm of rainfall through the irrigation season, which was November to March (inclusive). Table 2 describes the scenarios tested in this paper, the irrigation applied for each scenario and the resulting drainage. Irigation applied, the number of days irrigated, and the total drainage are lower for scenarios that use a just in time irrigation approach relative to those irrigating whenever water is available.

Table 2: Scenarios tested for Farm A, irrigation applied and drainage for each scenario per irrigation season (November to March). Data averaged from 18 irrigation seasons. Scenario name represents the number of guns (2 or 3), irrigation approach (J for just in time or A for always) and frequency limitation (M for minimum return interval or R for rostered).

<table>
<thead>
<tr>
<th>Name</th>
<th>Irrigators</th>
<th>Irrigation approach</th>
<th>Frequency limitation</th>
<th>Irrigation applied (m³)</th>
<th>Number of days of irrigation</th>
<th>Total drainage (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-JM</td>
<td>2 Guns</td>
<td>Just in time</td>
<td>Minimum return interval</td>
<td>437,325</td>
<td>90</td>
<td>20.4</td>
</tr>
<tr>
<td>2-AM</td>
<td>2 Guns</td>
<td>Always</td>
<td>Minimum return interval</td>
<td>749,700</td>
<td>154</td>
<td>260.7</td>
</tr>
<tr>
<td>2-JR</td>
<td>2 Guns</td>
<td>Just in time</td>
<td>Rostered</td>
<td>410,550</td>
<td>84</td>
<td>17.7</td>
</tr>
<tr>
<td>2-AR</td>
<td>2 Guns</td>
<td>Always</td>
<td>Rostered</td>
<td>749,700</td>
<td>154</td>
<td>260.7</td>
</tr>
<tr>
<td>3-JM</td>
<td>3 Guns</td>
<td>Just in time</td>
<td>Minimum return interval</td>
<td>425,756</td>
<td>92</td>
<td>17.6</td>
</tr>
<tr>
<td>3-AM</td>
<td>3 Guns</td>
<td>Always</td>
<td>Minimum return interval</td>
<td>708,050</td>
<td>153</td>
<td>225.4</td>
</tr>
<tr>
<td>3-JR</td>
<td>3 Guns</td>
<td>Just in time</td>
<td>Rostered</td>
<td>402,617</td>
<td>87</td>
<td>12.0</td>
</tr>
<tr>
<td>3-AR</td>
<td>3 Guns</td>
<td>Always</td>
<td>Rostered</td>
<td>708,050</td>
<td>153</td>
<td>225.4</td>
</tr>
</tbody>
</table>

Table 3 shows the economic results for the various scenarios. Pasture growth is annual total, and accounts for impact of irrigation on the shoulder seasons to be captured (e.g. pugging).

Table 3: Economic impacts for various irrigation scenarios for Farm A, standard deviation of annual variability in brackets.

<table>
<thead>
<tr>
<th>Name</th>
<th>Total direct costs</th>
<th>Pasture grown*</th>
<th>Pasture value</th>
<th>Total (value of pasture minus direct costs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$/ha/year</td>
<td>kgDM/ha/year</td>
<td>$/ha/year</td>
<td>$/ha/year</td>
</tr>
<tr>
<td>2-JM</td>
<td>$429 (±107)</td>
<td>13,732 (±475)</td>
<td>$3,116 (±128)</td>
<td>$2,688 (±108)</td>
</tr>
<tr>
<td>2-AM</td>
<td>$735 (±0)</td>
<td>11,311 (±1,088)</td>
<td>$2,646 (±217)</td>
<td>$1,911 (±217)</td>
</tr>
<tr>
<td>2-JR</td>
<td>$402 (±106)</td>
<td>13,997 (±417)</td>
<td>$3,172 (±123)</td>
<td>$2,770 (±145)</td>
</tr>
<tr>
<td>2-AR</td>
<td>$735 (±0)</td>
<td>11,311 (±1,088)</td>
<td>$2,646 (±217)</td>
<td>$1,911 (±217)</td>
</tr>
<tr>
<td>3-JM</td>
<td>$431 (±115)</td>
<td>13,960 (±452)</td>
<td>$3,165 (±124)</td>
<td>$2,733 (±125)</td>
</tr>
<tr>
<td>3-AM</td>
<td>$718 (±0)</td>
<td>11,360 (±1,238)</td>
<td>$2,642 (±245)</td>
<td>$1,924 (±245)</td>
</tr>
<tr>
<td>3-JR</td>
<td>$408 (±111)</td>
<td>14,150 (±344)</td>
<td>$3,207 (±101)</td>
<td>$2,799 (±120)</td>
</tr>
<tr>
<td>3-AR</td>
<td>$718 (±0)</td>
<td>11,360 (±1,238)</td>
<td>$2,642 (±245)</td>
<td>$1,924 (±245)</td>
</tr>
</tbody>
</table>

*Interpret PGR as relative to a ‘non-moisture limited’ scenario with no pugging or wastage. 16,121kgDM/ha/year
Figure 1 illustrates the relative value from each of the scenarios tested as well as the components of the direct economic costs for Farm A. The direct economic costs are a negative, whereas the value from pasture is a positive and the total value per hectare per year is also included.

**Figure 1**: Economic impact of various irrigation scheduling scenarios for Farm A, including value from pasture grown and direct cost components, total represents the value of pasture minus the direct costs.

**Discussion**

There is not a significant difference between the top four options (scenarios 3-JR, 2-JR, 3-JM, 2-JM). These top four options include two systems with additional irrigation infrastructure (3-JR and 3-JM) and two with the existing infrastructure (2-JR and 2-JM). Of these four top options, two use a roster to schedule irrigations and two use a minimum return period between irrigation, all four are based on a just in time irrigation approach. The distinction between roster and minimum return interval is driven by infrastructure restrictions on most farms, and while using a roster was slightly better economically, it was not significantly different across these top four scenarios. This indicates that there is no significant economic benefit in purchasing additional irrigation infrastructure. There is however, significant economic and environmental benefits in using a just in time approach relative to irrigating whenever water is available. The top four scenarios economically also had lower total drainage, indicating a positive environmental outcome. Based on this, the results for Farm A show the best option is to purchase the new irrigation gun and reduce their irrigation application depth and return length, and utilise a just in time irrigation approach (only irrigate when soil moisture indicates it is required) under a roster system (rather than minimum return).

Irrigation scheduling is limited by the flexibility of the irrigation infrastructure, at both a farm and a scheme level. At a farm level, irrigation scheduling decisions are constrained by the rotation lengths and application depth. Where this hydro-econ model can help improve outcomes, is by comparing how economic and environmental outcomes can change when these infrastructure limits are altered. The benefit of using a just in time irrigation approach rather than irrigating whenever water is available is to be expected (Srinivasan et al., _in preparation_). However, the lack of significant difference in total value and drainage between reducing irrigation application depth by 10mm and rotation length by two days, illustrated that Farm A should not necessarily invest in new infrastructure. This suggests that a commonly held view of irrigating smaller amounts more frequently can be beneficial for some farm situations, but there will be diminishing economic and environmental returns to investment in irrigation investment, so it will not always be the case.

A key assumption in this hydro-econ model is that water is available whenever the model decision rules wants to apply it. Another assumption is that labour and R&M costs are fully variable costs. In reality these are likely to be lumpy costs (Hall and Lieberman, 2012), and will not scale proportionally with each reduced irrigation day. In addition, this model does not address application uniformity and distributional accuracy, both of which can influence irrigation efficiency. Application uniformity is examined in depth in studies such as Hedley, Yule and Bradbury (2010), whilst distributional accuracy is examined by tools such as ‘bucket tests’ (DairyNZ, 2018a).
The hydro-econ model provides a way to compare economic and hydrological impacts of various irrigation scheduling decisions at a seasonal level, but it is not a marginal decision-making tool. There is currently not a tool in New Zealand which provides farmers with a predicted economic and environmental impact of each marginal irrigation scheduling decision, i.e. if they should turn the irrigator on today, and if so how much should they apply (if application depth can be varied). Access to this information is likely to help improve irrigation decision making both economically and environmentally. This hydro-econ model provides a starting point for a marginal decision-making tool for irrigation scheduling. Other areas for future research should consider, use of weather forecasts for irrigation decision making, varying soil types, partially variable labour and R&M costs and the economic impact of nutrients in any drainage water.

Conclusion

Application of a hydro-econ model to Farm A shows that there is a significant positive economic and environmental benefit from using soil storage-based scheduling rather than a rostering system. The lack of significant difference between reducing irrigation application depth by 10mm and rotation length by two days, illustrated that Farm A should not necessarily invest in new infrastructure. The results have a number of underlying assumptions that need further examination. This research provides an important first step in understanding the economic impact of marginal irrigation scheduling decisions.

References


Influence of El-Niño Southern Oscillation and Indian Ocean Dipole phases on annual pasture production in south eastern Australia

TMRS Perera*, BR Cullen and R Eckard

Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Parkville, Victoria 3010, Australia

*Corresponding author. E-mail: pererat@student.unimelb.edu.au

Abstract

The synoptic scale climate drivers El-Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) events can alter seasonal climate across south eastern (SE) Australia, but their influence on interannual variability of pasture production has not been fully described. Two indices were used to classify ENSO and IOD into three phases each in winter-spring period during 1950-2015. Statistical differences between ENSO and IOD phases (individually and combined) and annual pasture production, simulated at five sites (Wagga Wagga, Dookie, Hamilton, Ellinbank and Elliott) using DairyMod, were analysed using ANOVA. Mean annual pasture yields were substantially lower during El-Niño (EN) years at Wagga Wagga (7 t DM/ha.yr) and Dookie (6.4 t DM/ha.yr) than neutral and La-Niña (LN) years (~10 t DM/ha.yr) Similarly, IOD(+) years had lower yields at Wagga Wagga, Dookie and Elliott but not at Hamilton and Ellinbank. When combined ENSO-IOD phases were examined, the highest yields resulted when the LN phases coincided with IOD(-) or neutral, whilst the EN with IOD(+) phases led to the lowest yields. Analysis of sliding six-month windows revealed that yield difference started to emerge in March to August. This analysis highlights the importance of including combinations of large scale climate drivers to forecast pasture production with greater lead time.

Keywords

climate drivers; annual pasture production; DairyMod; yield forecasting

1.13 Introduction

In SE Australia, year to year climate variability poses a key challenge for managing pasture-based production systems. Frequent occurrences of unfavourable weather, such as severe drought, heat waves and extreme precipitation impact on pasture growth, quality and the key management decisions such as stocking rate, calving date and supplementary feeding (Cullen et al. 2009, Chapman et al. 2012, Harrison et al. 2016). Synoptic scale climate drivers such as El-Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) alone or in tandem can cause such anomalous weather, impacting on agricultural production in the key growing seasons (Potgieter et al. 2005, Hayman et al. 2010, Jarvis et al. 2018).

ENSO and IOD are two distinct modes of climate variability that alter seasonal weather conditions across Australia (Ashok et al. 2003, Wang and Hendon 2007). They develop by ocean (upwelling) and atmosphere (winds) interactions in the tropical Pacific and Indian oceans. ENSO phases usually swing between El-Niño(EN), La-Niña(LN) or neutral, and IOD changes between IOD(+), IOD(-) or neutral phases. EN and IOD(+) phases usually bring hot and dry conditions over Australia (Taschetto et al. 2011) while LN and IOD(-) phases support cool temperatures and above average rainfall (Ummenhofer et al. 2011). The conditions tend to be driest, when an EN event coincides with IOD(+) phase, while it could be extremely...
wet when a LN combines with IOD(-) (Ummenhofer et al. 2009). However, the impacts of each phase can vary in terms of their strength, temporal and spatial distribution across the region (Risbey et al. 2009, Risbey et al. 2013). A typical ENSO event starts in the first half of the year, peaks in the spring and gradually decays by the autumn but, LN phases can extend over several years. IOD events usually occur from May to November with their peaks occurring in the spring.

Several studies have investigated the influence of different phases of ENSO and IOD on agriculture in Australia. For example, LN events typically have higher wheat yield than EN (Nicholls 1985, Hayman et al. 2010), and IOD(+) phases have been linked to early maturity of wine grapes compared to IOD(-) phases (Jarvis et al. 2018). However, all these authors have reported varying special impacts, which means their influence on the rainfall and agricultural yields vary between sites or the region. The influence of these climate drivers on pasture production has not been fully described, even though the impacts are acknowledged. Therefore, the objective of this study was to investigate the effects of ENSO, IOD and ENSO-IOD combinations on annual pasture yields in SE Australia and to test the ability of climate driver phases to forecast pasture growth.

1.14 Materials and methods
1.14.1 Pasture growth simulation
The DairyMod biophysical pasture model (Version 5.7.4) was used to simulate daily pasture growth rates for two medium rainfall sites (Dookie in northern Victoria and Wagga Wagga in southern NSW) and three high rainfall sites (Hamilton in south western Victoria, Ellinbank in Gippsland and Elliott in Tasmania) over the period 1950-2015. At the high rainfall sites, perennial ryegrass (Lolium perenne L.) was simulated with either white clover (Trifolium repens L.) or subterranean clover (Trifolium subterraneum L.). At the medium rainfall site at Dookie, a phalaris (Phalaris aquatica L.) and subterranean clover pasture was simulated, while at Wagga Wagga, a phalaris, subterranean clover and annual ryegrass (Lolium rigidum L.) mixture was simulated. Pastures were simulated under non-limiting nutrient conditions and without irrigation at all sites so that responses to climatic variation could be identified. Pasture was harvested to a residual mass of 1.4 t DM/ha at the end of each month. Daily weather data obtained from the Bureau of Meteorology SILO data base (Jeffrey et al. 2001) (rainfall in mm, maximum and minimum temperature in °C, radiation in MJ/m² and evaporation in mm), plus measured CO₂ concentrations at Cape Grim baseline air pollution station, were used.

1.14.2 Classification of ENSO and IOD events
Multivariate ENSO index (MEI) bimonthly ranks (Data source: https://www.esrl.noaa.gov/psd/enso/mei/rank.html) in June/July to October/November, which represents the major pasture growing period and the peak times of the ENSO phases, were used to classify years into different ENSO phases. If at least 3 out of 5 bimonthly ranks showed a distinct ENSO signal, that year was categorised as either EN, neutral or LN, following the criteria used by Jarvis et al. (2018).

Dipole Mode Index (DMI) values calculated from the HadSST data set (Saji 2003) were used to identify IOD events from winter spring period. Based on the approach used by Cai et al. (2009) and Jarvis et al. (2018), the positive or negative IOD years were determined when the average DMI values (from June-November) were above or below +0.75 or -0.75 of its long term standard deviation, respectively. The years inside these thresholds were considered as neutral years. The years with different phases of ENSO
and IOD and their composites are shown in Table 1. The average climate statistics at each site during ENSO and IOD phases are in Table 2.

1.14.3 Statistical analysis

Analysis of variance (ANOVA) was performed at each site using Minitab (V.17) to check whether the means of annual pasture yields differed significantly during ENSO, IOD and ENSO-IOD combined phases categorised in the June-November period. The significantly different phases (P<0.05) were then tested with Fisher’s Least Significant Difference test to identify which phases were significantly different.

To investigate the ability of climate driver phases to forecast pasture growth, each year was categorised into ENSO, IOD and ENSO-IOD combined phases using sliding six monthly windows. Accordingly, six different periods were used (Jan-Jun, Feb-Jul, Mar-Aug, Apr-Sep, May-Oct, Jun-Nov). Mean annual pasture yields during those sliding windows were compared with ANOVA to identify significant yield differences between climate driver phases. Since the opposite phases of ENSO, IOD and their extreme phase combinations (EN/IOD+ and LN/IOD-) have shown the highest deviations from mean rainfall in most of the study sites in SE Australia (Table 2), (Risbey et al. 2009), yield differences were tested in those phases using 0.05 significance level. This approach allowed determination of the earliest time that the difference was significant and used it as an indication of forecast skill.

Table 4 Classification of ENSO, IOD and combined (ENSO-IOD) events from 1950-2015 using June-November values of MEI bimonthly ranks and DMI. Number of years that fall under each category is shown in parenthesis.

<table>
<thead>
<tr>
<th></th>
<th>IOD(+)</th>
<th>IOD(Neutral)</th>
<th>IOD(-)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2002, 2006, 2009,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2015 (13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1981, 1984, 1985,</td>
<td>196 (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1989, 1990, 1995,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1974, 1975, 1988,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1998, 2010 (11)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Mean annual rainfall (mm) and annual average daily temperatures (°C) with standard deviations for the ENSO and IOD phases at Wagga Wagga, Dookie, Hamilton, Ellinbank and Elliott. Coordinates of the sites were shown in parenthesis.
The effects of ENSO only and IOD only phases during June to November on mean annual pasture yields are displayed in Figure 1. Wagga Wagga, Dookie and Elliott sites had lower yields during EN years, but no differences were observed between neutral and LN years. The yield reduction in EN years when compared with LN years, was greater at the medium rainfall sites of Dookie (4 t DM/ha) and Wagga Wagga (3 t DM/ha) than at high rainfall site, Elliott (1.7 t DM/ha). Similarly, mean pasture yields were not significantly different between IOD(-) and neutral years, but IOD(+) years resulted in lower yields. The yield reduction compared to IOD(-) years was greater at Wagga Wagga (3 t DM/ha) and Dookie (3.3 t DM/ha) than at Elliott (1.6 t DM/ha) following a similar pattern to ENSO events.

Figure 1 Mean annual pasture yield (t DM/ha) during El-Niño, La-Niña and Neutral phases (a) and IOD(-), IOD(+) and neutral phases (b) at Wagga Wagga, Dookie, Hamilton, Ellinbank and Elliott sites. Significance of the ANOVA testing is displayed using asterisks at the bottom. The error bars indicate one-sided standard deviation and the significant differences are shown by different letters.
When analysed for the ENSO-IOD combined phases, mean annual pasture yields were significantly different (P<0.05) at the medium rainfall sites at Dookie and Wagga Wagga but not at the high rainfall sites (Fig. 2). In general, annual yields tend to be the lowest when EN phases coincide with IOD(+) phases and this reduction was generally greater (Fig. 2) than the reduction associated with each phase alone (Fig. 1).

Figure 2 Mean annual pasture yield (t DM/ha) during ENSO-IOD combined events at Wagga Wagga, Dookie, Hamilton, Ellinbank and Elliott sites. Significance of the ANOVA testing is displayed using asterisks at the bottom. The error bars indicate one-sided standard deviation and the significant differences are shown by different letters.

The pasture yield differences of LN – EN, IOD(+) – IOD(-) and LN/IOD(-) – EN/IOD(+) phases tested at six monthly sliding windows are shown in Figure 3. These yield difference became significant from the March-August period. Yield differences were higher at Dookie (eg: LN - EN= 4t DM/ha.yr) and Wagga Wagga (LN - EN= 3 t DM/ha.yr) and lower at Elliott (LN- EN=1.7 t DM/ha.yr).

Figure 3 Difference in mean annual pasture yield (t DM/ha) between LN-EN (a), IOD(-) – IOD(+) (b) and LN/IOD- and EN/IOD+ (c) for Dookie (thick line), Wagga Wagga (dotted line) and Elliott (dash line) for the climate driver classifications using sliding six-month time windows. The significant mean differences (P<0.05) are shown near each data point using asterisks.
1.17 Discussion
Hot and dry phases of both ENSO and IOD events had significant negative impacts on predicted annual pasture yields, independently and in combination, especially at the medium rainfall sites (Figs. 1,2). These results are consistent with the observed weather conditions during those climate driver phases in SE Australia (Table 2). The pasture yields during ENSO-IOD combined phases were influenced to a greater degree than when each phase occurred on its own because of the reinforcing effect of each climate driver phase when paired with the similar phase of the other driver (Risbey et al. 2009, King et al. 2014).

Understanding the impact of these climate driver phases will benefit those agricultural industries most affected by climate variability. Rainfed pasture production, which responds more strongly to rainfall variation, will benefit more if these event phases can be predicted before the key adapted management decisions are implemented (Ash et al. 2007). Management decisions to adapt to climate variability may involve planning for increased fodder conservation, early destocking or forward contracting of supplementary feed (Austen et al. 2002). However, accurate seasonal weather forecasting with sufficient lead time is still limited by the existing understanding of the complex ocean and atmospheric factors governing the strength and spatial extent of these phases (Henry 2006). A survey showed that farmers expected at least 70% forecast accuracy in order to use them in their decisions (Austen et al. 2002). Previous attempts have highlighted that the ENSO signal in the early season (March-May) is not often clear enough to influence farmers’ decision making (Hayman et al. 2010). The results of this study are consistent with this finding, whereby the sliding six-month windows indicated that significant pasture yield differences did not emerge until the March to August period. This yield difference remained significant for the rest of the year indicating that the climate driver phase signal is reasonably well predicted at the end of winter. Detailed analysis of each of the phases further revealed that 70% of the ENSO and 85% of the IOD phases recognised in the March-August period remained unchanged for the rest of the year while the probability that any phase may reverse in direction after this window was very low or zero.

1.18 Conclusions
The synoptic scale climate drivers, ENSO, IOD and ENS-OIOD combinations can significantly affect annual pasture production. This effect is greater at medium rainfall sites. The ENSO and/or IOD signal in the March-August period provides a reasonable prediction of the nature of the climate driver for the rest of the pasture growing period. However, adaptive decision making using ENSO and IOD forecasts needs an appropriate lead time. Therefore, further understanding of the dynamics of these climate drivers will pave the way for better management of grazing systems in SE Australia.
1.19 References


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Modelling biomass, soil water content and mineral nitrogen in dairy pastures: a comparison of DairyMod and APSIM

MT Harrison1*, M De Antoni Migliorati2, D Rowlings2, W Doughterty3, P Grace4 and RJ Eckard4

1Tasmanian Institute of Agriculture, 16-20 Mooreville Rd, Burnie, Tasmania, Australia 7320; 2 Institute for Future Environments, QUT, 2 George Street, Brisbane, QLD 4000, Australia; 3 NSW Department of Primary Industries, Elizabeth Macarthur Agricultural Institute, Woodbridge Rd, Menangle, NSW 2568, Australia; 4Faculty of Veterinary and Animal Science, University of Melbourne, Parkville 3010, Victoria, Australia

*Corresponding author. E-mail: Matthew.Harrison@utas.edu.au

Abstract

Realistic simulation of soil nitrogen cycling is important for quantifying nitrogen loss pathways to the environment, as well as the influence of N on pasture productivity. Although several models have been evaluated for their ability to simulate pasture growth, few studies have compared the models APSIM and DairyMod. Here, our objectives were to examine the capability of each model in simulating field measurements of pasture biomass, soil water content, mineral nitrogen and N2O emissions. For site one, DairyMod generally simulated mineral N, cumulative N2O and soil water with lower residual error than that from APSIM, but APSIM produced better estimates of pasture biomass. At site two, DairyMod produced more precise estimates of mineral N, but APSIM simulations were more reliable in terms of cumulative N2O. Overall this study demonstrated that both models produced satisfactory estimates of pasture biomass and soil water dynamics, but further research is necessary to diagnose reasons for the sometimes large discrepancies between simulated and measured mineral N and cumulative N2O emissions. Part of this discrepancy is likely to be caused by heterogeneity of soil N in the field, spatially and temporally. Although both models produce temporal estimates of mineral N and N2O, quantification of parameter uncertainty associated with spatial variation in mineral N would help improve model evaluation such as performed in this study.

Keywords

Ammonium; nitrate; mineralisation; mixed species sward; mineral nitrogen; intensive grazing system

Introduction

Reliable simulation of biophysical processes in intensive farming systems is important not only for estimation of environmental losses of N, but also for simulation of livestock profitability aspects related to pasture growth. Two models commonly used to simulate intensive grazing systems in Australia include APSIM (Keating et al., 2003) and DairyMod (Johnson, 2016). APSIM was designed for simulating biophysical processes in farming systems, initially with an emphasis on cropping systems, and more recently also for pasture systems. In contrast, DairyMod was designed predominantly for pasture-based systems. DairyMod operates has been shown to adequately simulate production aspects of pasture-based systems across diverse climates, soil types and pasture species (Johnson, 2016). Although developed for
different purposes, both models allow simulation of pasture growth as influenced by dynamics of soil water and nitrogen. APSIM has been validated at several pasture-based sites, but most past studies have been performed in the context of cropping systems; there are few studies of the performance of APSIM in simulating pasture growth in concert with mineral nitrogen, greenhouse gas emissions, and soil water content.

**Materials and Method**

Each model was calibrated using measurements collected from two field campaigns. Defoliation at both sites was conducted by mechanical cutting. The Camden site was located approximately 50 km SW of Sydney (-34.12S, 150.71E). The pasture at Camden was dominated by annual ryegrass (*Lolium rigidum*) and kikuyu (*Pennisetum clandestinum*). Fertiliser was applied at 46 kg N/ha immediately after every harvest in spring and autumn and every other harvest in summer and winter. Irrigation was applied through a combination of visual inspection of the pasture and soil moisture status. Soil mineral N was measured on a single core in each of three replicated plots. The Noorat site was located at the Glenormiston College Campus (38°10’S; 142°58’E) in Victoria; pastures at this site were dominated by perennial ryegrass. Urea was applied at a rate of 50 kg N/ha after every second defoliation until the end of the growing season each year. In 2012-13, after the low rainfall summer, the site suffered a severe decline in ryegrass density. As a result, oversowing was undertaken to improve ryegrass density of the pasture. At each harvest and seven days after nitrogen fertiliser application, samples of topsoil (0-0.1 m) were collected for NO$_3$ and NH$_4$ analyses. Four to six soil cores were collected from the four replicated plots of each treatment. Further details of this experiment are provided in Kelly (2013). APSIM classic v7.10 (Keating et al., 2003) and DairyMod v5.7.6 (Johnson, 2016) were parameterised with data from the two sites. Parameterisation was conducted for cumulative N$_2$O rather than for daily N$_2$O fluxes due to the variability of nitrous oxide measurements taken in the field (e.g. Fig. 1d). Several formulae were used for model evaluation following Tedeschi (2006); each metric was used to assess different qualities in the relationship between modelled and measured data. Mean bias (MB) was computed as the normalised difference between the observed and modelled mean; ideal MB values are zero. Root mean square error (RMSE) is the square root of the squared modelled values less the squared observations, divided by the number of observed values. Ideal RMSE values are zero. Mean prediction error (MPE) was calculated as the RMSE divided by the mean of the observed values. MPE values either < 0.10, 0.10-0.20 or >0.20 indicate good, moderate and poor simulation adequacy, respectively. The variance ratio (VR) was defined as the ratio of the variance of the observed data to that of the modelled data. The VR assumes ideal values when equal to unity; values greater than unity indicate that there is more variation in the actual data compared with the simulated data.

**Results and Discussion**

Evaluation metrics for the simulations conducted for the Camden and Noorat sites are shown in Tables 1 and 2, respectively.
Table 1. Assessment of DairyMod and APSIM simulations of biomass, soil NO$_3$ and NH$_4$, cumulative N$_2$O and soil water content in the surface layer (SWL$_1$) at Camden. Evaluation metrics compared data on a daily time-step.

<table>
<thead>
<tr>
<th>Model/variable</th>
<th>RMSE</th>
<th>$R^2$</th>
<th>MB</th>
<th>MPE</th>
<th>VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DairyMod/biomass</td>
<td>1234</td>
<td>0.05</td>
<td>-70</td>
<td>0.61</td>
<td>0.51</td>
</tr>
<tr>
<td>DairyMod/NO$_3$</td>
<td>26</td>
<td>0.11</td>
<td>11</td>
<td>0.79</td>
<td>2.02</td>
</tr>
<tr>
<td>DairyMod/NH$_4$</td>
<td>11</td>
<td>0.01</td>
<td>7</td>
<td>0.84</td>
<td>0.54</td>
</tr>
<tr>
<td>DairyMod/N$_2$O</td>
<td>540</td>
<td>0.94</td>
<td>-187</td>
<td>0.25</td>
<td>0.70</td>
</tr>
<tr>
<td>DairyMod/SWL$_1$</td>
<td>0.08</td>
<td>0.08</td>
<td>-0.01</td>
<td>0.21</td>
<td>0.90</td>
</tr>
<tr>
<td>APSIM/biomass</td>
<td>516</td>
<td>0.13</td>
<td>-171</td>
<td>0.26</td>
<td>1.98</td>
</tr>
<tr>
<td>APSIM/NO$_3$</td>
<td>41</td>
<td>0.07</td>
<td>31</td>
<td>1.22</td>
<td>5.97</td>
</tr>
<tr>
<td>APSIM/NH$_4$</td>
<td>14</td>
<td>0.03</td>
<td>13</td>
<td>1.04</td>
<td>22.60</td>
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<tr>
<td>APSIM/N$_2$O</td>
<td>719</td>
<td>0.80</td>
<td>401</td>
<td>0.33</td>
<td>0.77</td>
</tr>
<tr>
<td>APSIM/SWL$_1$</td>
<td>0.10</td>
<td>0.10</td>
<td>-0.03</td>
<td>0.27</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Simulated biomass from APSIM at Camden was generally better than that from DairyMod, with RMSE values for individual harvests of 516 and 1234 kg DM/ha, respectively, though $R^2$ values for both models were poor. This was caused by the transition between the annual ryegrass and kikuyu in autumn and late spring. For example, both models overestimated pasture biomass in late June of 2013 (Fig. 1), indicating that either both models are poorly designed with respect to simulation of mixed swards, both models were poorly parameterised, or that other factors limited pasture growth during this period, such as soil borne diseases, spatial nutrient variability etc. Changes in biomass from harvest to harvest from DairyMod tended to be more variable than that from APSIM; DairyMod overestimated ryegrass and kikuyu production at the start and end of the simulation at Camden (Fig. 1A). Simulated soil NO$_3$ and NH$_4$ by both models at each site was generally poor, particularly at Camden (Fig. 1). Simulated NO$_3$ from DairyMod was generally better than that from APSIM for both sites, as the daily NO$_3$ flux from the former model tended to be lower than that from APSIM (Fig. 1E). Simulated NH$_4$ from both models exhibited much greater variability than that in measured data (Fig. 1F). Although both models had NH$_4$-sensitive parameters (e.g. max denitrification/nitrification rate, NH$_4$ concentration for half maximum denitrification/nitrification rate in DairyMod), modification of such parameters typically only altered the magnitude of the NH$_4$ peak, rather than the rate of change of NH$_4$ in the soil solution (e.g. Fig. 1F). Consequently, the model assessment metrics in Tables 1 and 2 suggest that DairyMod was more reliable than APSIM in simulating trends in both NO$_3$ and NH$_4$, though this outcome was primarily caused by the lower temporal variability of mineral N from DairyMod cf. mineral N simulated by APSIM.
Fig. 1. Simulated and measured (A) pasture biomass, (B) weekly average soil water content, (C) cumulative weekly \( \text{N}_2 \text{O} \) flux rate, (D) cumulative daily \( \text{N}_2 \text{O} \) emissions, (E) soil NO\(_3\) and (F) soil NH\(_4\) from 14 October 2012 to 13 May 2014 at Camden, NSW, Australia.

Simulated cumulative \( \text{N}_2 \text{O} \) from DairyMod was more accurate than that from APSIM at Camden (Table 1 and Fig. 1D), though the converse was true at Noorat. Differences in \( \text{N}_2 \text{O} \) emissions between models was a partially caused by differences in denitrification and consequently \( \text{N}_2 \text{O}/\text{N}_2 \) ratios. In both models, \( \text{N}_2 \text{O}/\text{N}_2 \) ratios are calculated as a function of water-filled pore space (WFPS; the volumetric water content relative to saturation), and peaks of \( \text{N}_2 \text{O} \) are sensitive to the WFPS value at which denitrification begins (between drained upper limit and saturation), as well as NO\(_3\) concentration. Parameters specifying heterotrophic \( \text{CO}_2 \) respiration and gas diffusivity in the soil also affect the \( \text{N}_2 \text{O}/\text{N}_2 \) ratio in APSIM. For Camden, the
observed data had the greatest N$_2$O peaks around 21 February 2013 and 1 June 2013; these peaks generally coincided with peaks in observed soil water content (cf. Figs 1E and 1B). Compared with the observed data, simulated N$_2$O from APSIM had a lower baseline but with more peaks (Fig. 1C), somewhat reflecting the greater frequency of soil water peaks in the surface layer (Fig 1B). In contrast, simulated N$_2$O from DairyMod had fewer peaks than that from APSIM, and for Camden DairyMod simulated cumulative N$_2$O more reliably until the start of November 2013 (Fig. 1B).

Table 2. Assessment of DairyMod and APSIM simulations of biomass, soil NO$_3$ and NH$_4$, N$_2$O and soil water content (v/v) in layers 0-10 cm (SW$_1$), 10-20 cm (SW$_2$), 20-30 cm (SW$_3$) and 30-50 cm (SW$_4$) at Noorat. Data were compared on a daily time-step. Evaluation metrics are described in the methods.

<table>
<thead>
<tr>
<th>Model/variable</th>
<th>RMSE</th>
<th>R$^2$</th>
<th>MB</th>
<th>MPE</th>
<th>VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DairyMod/biomass</td>
<td>695</td>
<td>0.42</td>
<td>-313</td>
<td>0.56</td>
<td>0.61</td>
</tr>
<tr>
<td>DairyMod/NO$_3$</td>
<td>11</td>
<td>0.53</td>
<td>4.7</td>
<td>0.49</td>
<td>0.93</td>
</tr>
<tr>
<td>DairyMod/NH$_4$</td>
<td>23</td>
<td>0.25</td>
<td>3.8</td>
<td>0.98</td>
<td>1.59</td>
</tr>
<tr>
<td>DairyMod/N$_2$O</td>
<td>39</td>
<td>0.88</td>
<td>7.6</td>
<td>0.27</td>
<td>0.60</td>
</tr>
<tr>
<td>DairyMod/SW$_1$</td>
<td>0.06</td>
<td>0.71</td>
<td>0.00</td>
<td>0.22</td>
<td>0.91</td>
</tr>
<tr>
<td>DairyMod/SW$_2$</td>
<td>0.04</td>
<td>0.84</td>
<td>0.01</td>
<td>0.16</td>
<td>0.87</td>
</tr>
<tr>
<td>DairyMod/SW$_3$</td>
<td>0.03</td>
<td>0.93</td>
<td>-0.03</td>
<td>0.12</td>
<td>0.83</td>
</tr>
<tr>
<td>DairyMod/SW$_4$</td>
<td>0.03</td>
<td>0.85</td>
<td>0.01</td>
<td>0.07</td>
<td>1.55</td>
</tr>
<tr>
<td>APSIM/biomass</td>
<td>660</td>
<td>0.19</td>
<td>-405</td>
<td>0.54</td>
<td>1.02</td>
</tr>
<tr>
<td>APSIM/NO$_3$</td>
<td>25</td>
<td>0.02</td>
<td>-6.4</td>
<td>1.08</td>
<td>0.72</td>
</tr>
<tr>
<td>APSIM/NH$_4$</td>
<td>31</td>
<td>0.02</td>
<td>-0.6</td>
<td>1.30</td>
<td>1.29</td>
</tr>
<tr>
<td>APSIM/N$_2$O</td>
<td>14</td>
<td>0.97</td>
<td>5.0</td>
<td>0.10</td>
<td>0.82</td>
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<tr>
<td>APSIM/SW$_1$</td>
<td>0.04</td>
<td>0.87</td>
<td>0.02</td>
<td>0.15</td>
<td>0.93</td>
</tr>
<tr>
<td>APSIM/SW$_2$</td>
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<td>0.02</td>
<td>0.13</td>
<td>0.95</td>
</tr>
<tr>
<td>APSIM/SW$_3$</td>
<td>0.02</td>
<td>0.88</td>
<td>0.01</td>
<td>0.08</td>
<td>0.94</td>
</tr>
<tr>
<td>APSIM/SW$_4$</td>
<td>0.03</td>
<td>0.85</td>
<td>0.01</td>
<td>0.07</td>
<td>1.55</td>
</tr>
</tbody>
</table>

CONCLUSIONS

This study has demonstrated a need for calibration of models to multiple sites when comparing simulations of mineral N, N$_2$O emissions and soil water content, as well as increased replication of field data to provide an indication of variability. Our results showed that the “right” answer can be achieved for the “wrong” reasons; coefficients used in N$_2$O algorithms in both models could be manipulated after having calibrated mineral N, allowing reasonable estimation of cumulative N$_2$O even though simulated NO$_3$ and/or NH$_4$ exhibited a temporal dynamic that was not present in the data. In addition to daily data, future modelling of mineral N should thus consider conducting validation over longer periods (e.g. weekly averages) due to the tendency of NO$_3$ and particularly NH$_4$ to fluctuate widely in short time spans. More frequent field measurements of mineral N would also be useful in this regard. The discrepancies between measured and modelled mineral N are likely partially due to both modelled and measured data; existing model equations and model parameterisation may not be sufficient to capture the complexity of biological processes influencing mineral N content such as mineralisation, nitrification and denitrification. On the other hand, the temporal and spatial variability of mineral N in the field may not have been adequately captured in the measured NO$_3$ and NH$_4$ data.

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Making virtual fencing work for individual dairy cattle

S. Lomax\textsuperscript{a,b}, P. Colusso\textsuperscript{a} and C.E.F. Clark\textsuperscript{a}

\textsuperscript{a}Dairy Science Group, \textsuperscript{1} School of Life and Environmental Sciences, Faculty of Science, The University of Sydney, NSW 2570

\textsuperscript{b}Corresponding author. Email: Sabrina.lomax@sydney.edu.au

Short title: Virtual fencing for dairy cows

Abstract

Virtual fencing (VF) has the potential to revolutionise the control of livestock movement. Cattle can associate an audio cue (AC) with an electrical stimulus (ES), however, it is important to understand the variation in response between individuals to effectively implement this technology. We investigated individual learning of a virtual fence in dairy heifers and cows. Twelve multiparous Holstein-Friesian (HF) cows and 11 HF rising two-year-old heifers were offered a maintenance feed ration and subjected to a laneway test using manual VF collars. A VF line was set halfway down a 50m laneway with grain-based concentrate at the end. Each cow was tested 6 times over 5 days. The AC was administered for 2 seconds at the VF as per proposed commercial devices and an ES (2,200V) for < 1 sec only with forward movement past the VF. Access to grain-based concentrate and number of AC and ES were recorded. Cows were less (P<0.05) likely to go through the VF than heifers (66 vs 96%, respectively) to access feed. Cows also received less (P<0.05) paired cues than heifers (1.8 vs 2.4, respectively). Results suggest that training approaches should be tailored to age (lactation number) or experience. Our novel findings highlight the need for refined training protocols to ensure that VF works for all dairy cattle.

1.20 Introduction

Modern-day farm structures present new challenges for pasture-based livestock systems. As herd size increases, and farm numbers decrease the management of livestock in these systems becomes increasingly challenging. Within pasture based dairy systems, rotational or strip grazing management practices require flexible fencing for the control and containment of cattle, however this is associated with increased labour, cost and practicality constraints.

Virtual fencing technology involves the control of an animal’s location without the use of fixed or ground-based fencing (Umstatter 2011). Cattle have been successfully trained to avoid an area or feed attractant through a paired audio cue and electrical stimuli, delivered through radio-controlled collars (Lee \textit{et al.} 2009; Umstatter \textit{et al.} 2013; Umstatter \textit{et al.} 2015; Campbell \textit{et al.} 2017a; Campbell \textit{et al.} 2017b). A recent study found that variation in individual beef heifer response to VF cues impacted on the rate of learning (Campbell \textit{et al.} 2017b). This has implications for implementation of this technology in pasture based dairy systems. Furthermore, there is no work documenting the effect of age or experience on learning or response to VF. There is a need to gather information on the variation in individual response to, and learning of these VF cues, to determine the need for training for practical and commercial applications.
The most recent work documents success in beef cattle and sheep in extensive grazing environments (Brunberg et al. 2015; Brunberg et al. 2017; Campbell et al. 2017a; Campbell et al. 2017b). The question remains as to whether learning and response differs between individuals, if this is affected by age, and how this applies to dairy systems. The objective of the current study was to determine the variation in animal learning and behavioural response to a virtual fence between dairy cows (naive to VF) of two age groups.

1.21

1.22 Materials and Methods

1.22.1 Ethical statement

The experiment was approved by The University of Sydney Animal Ethics Committee (AEC 2016/1114) prior to commencement.

1.22.2 Animals and management

The experiment was conducted across two blocks over a 3-month period between May and July, 2017. A total of 23 female cattle (aged 1-7 years) were used in the study comprising of 12 non-lactating, multiparous Holstein-Friesian (HF) dairy cows (4 to 7 years old), 11 HF heifers (14-18 months old), selected from the commercial dairy herd at The University of Sydney’s dairy farm, Corstophine. All animals were naïve to the VH technology and methodology.

For the duration of the habituation and test period, cattle were housed in a large 100m x 80m paddock, the “home pen”, adjacent to the test site with access to shade and water (Figure 1). Animals were fed a maintenance ration of Lucerne hay (dry matter 89.1%, crude protein 16.4%, metabolizable energy 8.5%). The maintenance requirement was determined through the formula: MJ of energy required per cow per day $= 0.67 \times \text{BW}^{0.75}$; where BW = live weight of the cow (Corbett et al. 1987). This formula incorporates the individual weight of the cow and the dry matter of the feed to determine the kg of feed required per day to maintain body weight. Approximately 1kg of grain-based concentrate (“Cattle Supreme” pellets, Vella Stock Feeds Plumpton, NSW Australia; energy 11.25MJ/kg, protein 16%, calcium 1.2%, phosphorous 0.5%, fibre 8%, salt 1.25% dry matter) was offered as a feed attractant in the test arena during habituation and testing. All cows were provided ad lib access to water via troughs in the home pen.

1.22.4 Study Design

The study was performed across 2 blocks of 12 days, with 11-12 animals tested within each block. The animals were habituated to the home pen, the test laneway, and the virtual fence (VF) collars on days 1 to 7. During this time animals were trained to access a pelleted feed attractant in a feed trough at the end of the test laneway (L50m x W4m). The individual response of cattle to VF cues emitted from manually controlled collar mounted devices was tested in a laneway. Animals were individually tested in the laneway 6 times between days 8 and 12. Positive reinforcement was conducted between each test, to ensure each cow freely accessed the feed attractant before testing again.

1.22.6 Habituation and training

On day 1 of habituation the animals were moved into the yards and weighed. The animals were moved through the yards four times on day 1, where they were held in the crush for 2 minutes each time to acclimatise them. An 8cm x 8cm area of skin was shaved on the right side of their neck to allow for
optimal contact with the collar electrodes. Training commenced on day 2 of habituation. Each morning animals were moved individually into the crush where the VF collars were attached. The device was fitted to the right side of the neck, to ensure electrode contact with the shaved patch of skin and held in place by a 500g counterweight. On days 2-7 the cows were trained to access the pellet feed attractant at the end of a laneway (Figure 1) four times per day. For each training period, cows were allowed a maximum of 2 minutes in the laneway to access the pellets. Cows received no cues during training.

1.22.7
1.22.8 Manually operated virtual fence collars

The virtual fence (VF) was simulated using collar-mounted devices that were manually controlled for delivery of audio and electrical stimuli. These devices incorporated a modified dog training device (ET300 mini Educator, E-Collar Technologies Inc, USA) within the casing of a commercial cattle health monitoring collar (Moo Monitor, Dairymaster, Ireland). The collars were controlled via a remote device with separate buttons to deliver the audio cue and electrical stimuli. The location of the VF line was marked at 25m of the laneway, using red paint on the outside edge of the relevant fence post, so that it was visible to the person delivering the cues, but not visible to the animal in the laneway. As the animal approached the VF line, the operator delivered a 2.5s audio cue (Campbell et al. 2017b). If the animal stopped and/or turned away from the audio cue, no electrical stimulus was applied. If the animal continued toward the feed trough the operator administered the electrical stimulus (2,200V, 1.42mA, 58µs pulse width) for less than 1 second. This sequence was repeated if the animal continued forward, ensuring that each electrical stimulus was preceded by an audio cue. Once an animal reached the feed trough, the test ended, cues ceased and it was allowed to consume the pellets. This was designed to emulate a pasture based scenario where cows would be rewarded by fresh pasture if they crossed the virtual fence. Each animal was allowed a total of 2 minutes in the laneway per test, in which time if the animal returned back to the gate after receiving the cues, the test ended. There was a maximum of 5 electrical stimuli allowed per animal per test.

1.22.9
1.22.10 Experimental protocol

Animals were tested 6 times across 5 days between days 8 and 12. Each collar was fitted to an individual animal, so that each animal wore the same collar for every test. Animals were individually tested in random order in the morning between 0900h and 1100h and/or in the afternoon between 1400h and 1600h (maximum 2 tests per day). Individual testing was conducted out of sight of the other cattle. For testing, individuals were moved through the race and crush into a small holding area before the gate to the laneway (Figure 1). The gate was then opened, and once the animal’s back legs had crossed the entry gate into the laneway, the stopwatch was started. Each animal was allowed a maximum of 2 minutes per test to approach the feed trough. Upon conclusion of the test the animal was walked back to the holding yard.

Between tests, animals were allowed to individually access the pellets without receiving any cues or stimuli, as a “positive association” to the laneway. This was repeated until all individuals were freely accessing the pellets, so as to break any negative spatial association with the laneway. Upon the conclusion of testing each day, the VF collars were removed and the animals returned to the home paddock where they were fed their daily maintenance ration. The number of audio and electrical stimuli
received by each cow, and whether an individual cross the VF line and reached the feed attractant (Yes = 1, No = 0) were recorded.

1.23

1.24 Statistical analysis

A generalised linear mixed model (GLMM) for binomial proportions was fitted for the access to feed in Genstat® (16th edition, VSNi UK). Random effects of Animal ID nested within Date were included, and the individual fixed effects of Test number, Time of Day (AM/PM), Cow/Heifer and their interactions were tested.

A GLMM was used to analyse the Poisson distributed outcome of the number of paired audio and electrical stimuli received Genstat® (16th edition, VSNi UK). For all analyses statistical significance was determined at P<0.05.

1.25 Results

1.25.1 Access to feed

Results are presented as the proportion of time that the VF was “broken” and the feed accessed. There were no significant interactions, therefore mean effects are presented. There was no significant effect of time of day (P = 0.724) on access to feed. There was a significant effect of Test (P <0.001, Table 1) and Cow/Heifer (P =0.003) on access to feed. Cows accessed the feed attractant past the VF line 66% of the time, compared to 96% of heifers.

Table 5 – proportion of animals accessing the feed attractant past the VF line and mean number of paired audio and electrical stimuli received by animals across consecutive tests. "abc" Means with different superscripts differ significantly.

<table>
<thead>
<tr>
<th>Test#</th>
<th>Percentage access feed</th>
<th>Average count of paired audio and electrical stimuli</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>93.2a</td>
<td>2.2</td>
</tr>
<tr>
<td>2</td>
<td>92.4a</td>
<td>2.2</td>
</tr>
<tr>
<td>3</td>
<td>73.3bcd</td>
<td>1.9</td>
</tr>
<tr>
<td>4</td>
<td>61.6b</td>
<td>1.5</td>
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<tr>
<td>5</td>
<td>75.4cd</td>
<td>1.8</td>
</tr>
<tr>
<td>6</td>
<td>82.4d</td>
<td>2.1</td>
</tr>
<tr>
<td>P-value</td>
<td>P&lt;0.001</td>
<td>P = 0.09</td>
</tr>
</tbody>
</table>

1.25.2

1.25.3 Number of audio cues and electrical stimuli received

The average count of paired audio and electrical stimuli received is presented in Table 2. There was no significant effect of time of day on stimuli received. Heifers received more (P=0.05) paired stimuli...
(2.3) than cows (1.8). There was a statistical tendency (P=0.09) for the number of paired stimuli to change across tests (Table 1), with a reduction in stimuli until test 4.

1.26

1.27 Discussion

This study contributes important information to understanding individual cow learning and response to virtual fence cues, and the effects of age.

An important finding in this study is the significant difference in response between heifers and cows. While both had a high proportion of animals reaching the feed attractant, heifers did so almost all of the time, and received almost double the number of paired stimuli. This may be due to lack of prior learning of conventional electric fencing systems, an area which warrants further investigation. Learning may be impacted by age and experience however there is limited literature comparing learning in multiparous cow and heifers. A study by Costa et al. (2016) found that heifers grouped with experienced cows had a shorter latency to begin grazing as compared to non-experienced heifers when learning how to graze. These findings have implications for how we train heifers and cows to virtual fencing systems.

There was a reduction in the proportion of animals accessing the feed attractant, and the number of paired stimuli received, between tests 1 and 4, which indicates less interactions with the fence line and implies animal learning. This supports the findings of Lee et al (2009), which reported an increase in the proportion of beef heifers responding to cues, and avoiding a feed attractant in an earlier study. Furthermore, Campbell et al. (2017b) found a similar response, where the majority of heifers accessed a feed attractant in the first 3 trials, with a significant reduction from Trials 4 to 8. In the current study, the number of paired stimuli, and proportion of animals accessing feed, increased between the Tests 4 and 6, where it was noted that cattle became frustrated as test number increased. The constraints of the study design, using a 4m x 50m laneway, and a unidirectional approach to a feed attractant, may explain this reduction in response to the VF cues after Test 4. Individual testing under the current experimental conditions, presents an artificial environment that limits the extent to which we can determine animal response on a herd level. Future studies will focus on a reduced number of tests, with a change in location between tests to reduce spatial association (Umstatter et al. 2015).

Under the conditions of the current experiment the manual VF collars were not successful in excluding the majority of cattle from the pellet feed attractant. The cattle were fed on a maintenance ration of hay during the test period, and were given high quality pellets as a feed attractant, which poses the question of whether the cattle’s feed motivation and/or hunger were greater than their response to the electrical stimuli delivered.

A limitation of using the manual collars, is the inconsistency in the duration of stimuli delivery. The use of automated collars may aid in improving response.

These findings have implications for the real-world application of this technology in pasture-based systems. There is great potential to contain cows using virtual fence technology, however training presents an important first step to reduce the variation in individual response.
1.28 Conclusion

Overall, the results of this study indicate that there is a high level of variation in how individuals respond to VF cues. Some animals are able to learn a virtual fence, however a large proportion of animals within the context of the experimental conditions accessed the feed attractant past the VF. The conditions of testing individuals in a laneway setup has limitations when trying to understand how animals may respond in a strip grazing scenario, however provides important information on how heifers and cows differ in learning and response. Future work should focus on the impact of hunger on learning and response to VF cues, and how training may be applied to ensure that all animals respond correctly.

Figures

Figure 1 - test setup for individual laneway testing. A feed attractant of a grain based concentrate dairy pellet was placed at the end of a 50m laneway. A VF line was set halfway (25m) down the laneway. Cows would receive an audio cue (AC) for 2 sec when they reached the VF line. If they continued forward, they would receive an electrical stimuli (ES) for <1sec. Testing was for a maximum of 2 min. Access to feed (1 Yes/ 0 No) and number of stimuli were recorded.
1.29 References


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The changing face of dairy in Victoria – are we ready for it?

YJ Williamsa*, S McDonaldb, SJ Chaplina

Agriculture Victoria.

bTatura Centre. 255 Ferguson Rd, Tatura Victoria, Australia 3616
Cnr Annesley St & Ogilvie Ave, Echuca Victoria, Australia 3564

Corresponding author: Yvette Williams, 255 Ferguson Rd, Tatura Victoria, Australia 3616. Phone: +61 3 5833 5375. Email: Yvette.Williams@ecodev.vic.gov.au

Short title
Planning and development of intensive dairy

Abstract
The last 5 years has seen unprecedented growth and development of intensive dairy production systems in Victoria. In these systems cows are permanently confined to sheds with their feed supplied as a total mixed ration. This is creating challenges for dairy farmers, local governments and the industry in the area of land-use planning. We examined current land use planning provisions and industry guidelines for their applicability and suitability to the implementation of intensive dairy production operations in Victoria. The majority of the legislations examined pose no issues to the development of large scale intensive dairy operations, however there are some aspects that do, or have the potential to, create confusion and difficulties particularly in the area of planning. New animal production definitions under the land-use planning code provide an unequivocal definition for intensive dairy farms with the inclusion of their own specific category. Separation distances used for intensive dairy farms are prohibitive for development and are inconsistent with other intensive livestock industries. A code for intensive dairy farming is required and would provide the opportunity to generate data for sound research-based operational standards.

Keywords
buffer distances, amenity, odour, barns, freestalls

Introduction
Dairy farming in Victoria has traditionally been a low to medium cost (Doyle et al. 2000, Clark et al. 2013) pasture-based industry and currently accounts for around two thirds of Australia’s total milk production (Dairy Australia 2017a). Supplementation with concentrates, grain and byproducts occurs to varying extents across farms (Jacobs 2014, Wales and Kolver 2017), with the annual average fed currently amounting to around 1.6 t DM/cow (Dairy Australia 2015a). Infrastructure, such as feed pads for feeding cows has become more common in the last 10 years (O’Keefe et al. 2010), and in the last five years significant investment in farm and resource assets has seen intensive dairy concepts progress to fully operational systems. Intensive animal production is a farming system where the animals are permanently confined to sheds or pens without the opportunity to graze, and with all of their feed supplied inside the enclosures. Intensive dairy production in Australia is usually carried out using one of
two barn-based setups - freestalls or loose-housing on a bedded pack (Bewley et al. 2017) - with cows fed a total mixed ration.

Since 2015 Agriculture Victoria has undertaken discussions with at least 30 farmers and/or investors, mainly in the northern part of the state, who were proposing to develop a new intensive dairy farm, transition their current production system to one that is fully housed, or expand their already intensive operation. Although this number only comprises around 2% of dairy farms in the Murray Dairy Production region (Dairy Australia 2017a), it is likely to only be around half of the farms who are considering these systems (P. Wallace, Agriculture Victoria). Intensive systems are being considered across a range of herd sizes, with the majority so far encompassing 500-1,500 cows. Around 20% of the developments are being designed with multiple barns to house large (2000+) numbers of cows at a single site. These proposals, in total, are planned to house in excess of 40,000 cows, which is around 12% of the cows in the Murray Dairy region (Dairy Australia 2017a).

Our observations are that it has been a challenge for development proponents to obtain appropriate planning approvals due to inadequate industry codes and guidelines, and that lengthy delays in planning and increased mediation have brought several applications to a halt. Council planning departments often lack the technical knowledge of the dairy industry to enable them to deal with the complexity of the applications, and this is also exacerbated with planning controls that do not reflect current farming systems. As such, expertise outside of local government is often sought to assess the suitability of applications. To complicate the process further, large intensive dairy developments are attracting greater attention from community, environmental and animal welfare groups. Responding to these submissions requires extra resources from within the councils and may even result in development cases being referred to State Government level to determine the outcomes.

As an extension to a government commissioned review (AIAC 2016, DELWP 2017a) into how the planning system supports current animal industries we further investigated current legislations and industry guidelines with the aim of clearly identifying factors that have the potential to hinder the growth and expansion of existing dairy production systems into intensive animal husbandry businesses, and the establishment of new intensive dairy enterprises in Victoria.

Method

To undertake this review, Victorian regulations, guidelines and best management practices were examined to determine at what point, if any, they were a hindrance to the development of large intensive dairy operations. We also examined recommendations made by the Animal Industries Advisory Committee (AIAC) in their review of the role of the planning system in supporting the establishment and expansion of animal industries (AIAC 2016). Recommendations were then made as to which regulations, guidelines and best management practices required updating and what new information needed to be generated in order to provide clarity for those making and assessing planning submissions.
Results

There are many legislative Acts, at both State and Commonwealth level, and associated mandatory policies, provisions, regulations, codes and standards regulating the development of dairy farming enterprises in Australia (Table 1.). A review of these legislations showed that the majority present no hindrance to the development of larger scale intensive dairy operations in Victoria. However, there are some aspects that do, or have the potential to create confusion and difficulties, particularly in the area of planning. These include: land use planning definitions, separation distances recommended for dairy operations, and the lack of an incorporated code of practice for intensive dairy farming.

Table 1. Acts of Parliament, associated policies and standards that are relevant to the planning and development of large, intensive dairy production operations in Victoria, Australia.

1.30 Aboriginal Heritage Act 2006

1.31 Catchment & Land Protection Act 1994

1.32 Environment Protection Act 1970
   State Environment Protection Policy (Waters of Victoria) 2003
   State Environment Protection Policy (Groundwaters of Victoria) 1997
   State Environment Protection Policy (Prevention and Management of Contamination of Land) 2002
   State Environment Protection Policy (Air Quality Management) 2001
   Environment Protection (Scheduled Premises and Exemptions) Regulations 2017
   Noise from industry in regional Victoria (EPA*, 2011)

1.33 Recommended separation distances for industrial residual air emissions (EPA, 2013)

1.34 Environment Protection Biodiversity Act 1999

1.35 Flora and Fauna Guarantee Act 1988

1.36 Occupational Health and Safety Act 2004
   Occupational Health and Safety Regulations 2017

1.37 Planning and Environment Act 1987

1.38 Victoria Planning Provisions 2016

1.39 Road Management Act 2004

1.40 Water Act 1989
   Water (Irrigation Farm Dams) Act 2002

*EPA – Environmental Protection Authority
The main advisory publication suitable to assist with the planning and development of intensive dairy farms in Victoria is ‘Guidelines for Victorian Dairy Feedpads and Freestalls’ (O’Keefe et al. 2010). While this publication is suitable for guiding farm developments involving a permanent cow housing system, it has not been developed for systems requiring multiple free stall enclosures or barns on one site and it does not accommodate dairy feedlots.

Discussion

1.41 Land Use Planning Definitions

The use, development and protection of land in Victoria is governed by the policies and requirements set out in the Victoria Planning Provisions (VPP; DELWP 2016). Planning departments in local council and shire offices are responsible for administering the VPP and issuing planning permits for agricultural developments in their respective localities. The VPP includes a set of land use terms (clause 74) that describe potential uses or activities in relation to the land. These terms are linked to the need for planning permits so that activities or uses with greater potential for negative off-site impacts on amenities, such as odour, noise and dust, have more controls placed on them. While the focus of off-site impacts in relation to land-use planning is around amenity for nearby land users, this does not remove the need for animal industries to adhere to the Environmental Protection Act (1970), which deals with land, air and water pollution, and Public Nuisance laws.

Until recently animal husbandry was dichotomously categorized, under the VPP, as either intensive or extensive based on the source of the feed (DELWP 2016). If the animals’ main food source was obtained by grazing plants grown on the land, then the husbandry was defined as extensive. Conversely, if most of the food for the animals was imported from outside the enclosures, it was defined as intensive animal husbandry. There were also specific definitions under the intensive category for beef cattle feedlots, broiler farms and piggeries, which are linked to the industries’ codes of practice. While this definition for intensive animal husbandry was ambiguous for many of the production systems and practices undertaken today on dairy farms, due to having no specific definition for ‘most of the food,’ it was suitable for the large, fully housed dairies that are the focus of this review.

From September 2018 new Animal Production definitions (DELWP and DEDJTR 2018) were enacted to remove the current ambiguity of classifying grazing and intensive animal enterprises. Extensive animal production will now be replaced with grazing animal production and is defined as ‘where the animals’ food is obtained by directly grazing, browsing or foraging plants growing on the land.’ The definition also allows for any level of supplementary feeding. Intensive animal production will now be defined as ‘where the animals’ food is imported from outside the immediate building, enclosure, paddock or pen.’ Grazing animal production is specifically excluded in the intensive animal production definition. Additionally, a specific category for Intensive Dairy farms has been created under the intensive animal production category. This definition is now unequivocal for large, fully housed dairies.
1.42 Separation Distances

An important aspect in the development of intensive animal operations is ensuring that there is an adequate distance from existing sensitive land uses, such as residential buildings, surface and ground water resources, and the farms property boundary for the protection of amenity and the environment. These distances are known as separation, or buffer, distances. Urban encroachment on livestock enterprises, particularly farms that are expanding or intensifying their operations, is resulting in increased conflicts between residents and farmers, highlighting the need for improved land use definitions and appropriate classifications of current livestock practices so that suitable separation distances are applied.

To assist with ensuring separation distances are adequate, the VPP instructs that planners consider the separation distances outlined in the Recommended Separation Distances for Industrial Residual Air Emissions (EPA 2013). These distances have been recommended to minimise off-site impacts arising from unintended, industry-generated odour and dust emissions. Stock feedlots are specified in these guidelines and are defined as ‘where animals are confined for the purpose of agricultural production; beef or dairy’. This definition is ambiguous depending on how the term ‘confined’ is applied to animal production operations.

The recommended separation distances for beef and dairy operations differ. For beef feedlots a separation distance is calculated by taking into account the design and management of the feedlot, the stocking density, the type of sensitive land use, the terrain characteristics and the vegetation cover (Victorian Feedlot Committee 1995). With this approach, the separation distance required for a town is calculated to be more than that for a single dwelling. For example, a 2,000-head beef feedlot may need to be around 3,000 m from a town (>2,000 people) but only 600 m from a single dwelling.

For dairy feedlots the recommended separation distance is 5,000 m for all sensitive land uses. Anecdotally both domestic and foreign dairy investors have identified this as a significant barrier to the development of new operations and the expansion of existing large dairy properties, particularly should they intend to shift into confined animal operations in the future. In current dairy farming locations there would be very few residences that have 5,000 m or more between them and another residence, making it extremely difficult to site large intensive dairy operations in these areas.

To address this issue, new methodology for the calculation of appropriate separation distances for intensive dairy farms is required. Ideally the method would be similar to that in the Victorian Code for Cattle Feedlots, allowing for some consistency between industries. There is no local data available to enable the modelling of odour generation and dispersion from intensive dairy farms and the different style of housing and thus the types and amounts of effluent generated in beef feedlots, means that data suitable for beef cattle feedlots may not be applicable to housed, intensive dairy operations. Investigation of odour emission data from intensive dairy operations overseas to assist with separation distance modelling for intensive dairies in Victoria is a logical starting point. An accepted and robust method for calculating separation distance for intensive dairies is required to add predictability and certainty to planning applications. It should also be noted that for separation distances to be effective in decision making they need to be given statutory effect (AIAC 2016).
1.43 Industry Codes of Practice to Assist Planning Approval

Piggeries, broiler farms and beef cattle feedlots have industry codes of practice incorporated under the VPP to facilitate design, construction and operational standards in these intensive animal industries under Victorian conditions (Code of Practice Piggeries 1992, Victorian Feedlot Committee 1995, Victorian Code for Broiler Farms 2009). These incorporated codes provide a more rigorous framework of accepted principles which enables the associated environmental and public amenity risks or impacts of these operations to be managed. The piggeries and cattle codes are currently under review to ensure they better reflect emerging farming systems and industry best practice, given these codes were developed over 20 years ago. There is currently no code for intensive dairy farming.

An industry code of practice for intensive dairy farming would provide all parties involved in the design, development, assessment and approval of intensive dairy farms with a clear set of standards and requirements that aim to mitigate environmental and social impacts (AIAC 2016). It would provide more certainty and consistency in the planning and assessment and approvals process for new developments and provide a structured basis for assessment and verification of the ongoing compliance with appropriate operational standards. The standards that form the basis of an intensive dairy code need to come from a sound research base. This provides an opportunity for the industry to identify significant gaps and inconsistencies in information and generate data that is specific for its needs, for example odour emissions from dairy barns that will inform separation distance calculations.

Conclusions

While the changes to land use definitions will provide clarity for those involved in the planning and development of large intensive dairy farms, there needs to be a standard methodology developed for determining separation distances. The development of a code for intensive dairy farming would provide the opportunity to generate data that is specific to the industry’s needs, ensuring operational standards have a sound research base.

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References


1.44 Legislation

Environmental Protection Act 1970 (Vic)
Responding to Pressures to Adopt Environmentally Sustainable Practices: Farm Environmental Plans as “Boundary Objects”

FD van Noppen1*, JI Reid1, K Hytten1, DJ Horne1, L Burkitt1

1School of Agriculture and Environment, Massey University - Te Kunenga ki Pūrehuroa, Palmerston North, Aotearoa New Zealand

*Corresponding author. E-mail: f.d.vannoppen@massey.ac.nz

Abstract

How farmers navigate pressures to adopt increasingly environmentally sustainable farm practices can inform organisations including local government agencies and enable support for change initiatives. This paper presents preliminary findings from a case study of a dairy farmers’ discussion group in Hawke’s Bay, Aotearoa New Zealand. This discussion group represents an example of an initiative seeking to address recognised, local water quality issues. Farmers indicated that they perceived pressure from industry, the public, local government and a local community group to change practices in order to improve local water quality. Farmers reported proactive implementation of environmentally sustainable practices, but expressed that these efforts were not acknowledged. Farmers expressed a desire to address negative perceptions of dairy farming; recognising the influence of negative societal perceptions upon their social licence to operate. The farmer discussion group responded collectively by developing Farm Environment Plans (FEPs), in part as evidence of their efforts with regard to environmental sustainability in their farms. This unconventional way of using farm plans to demonstrate environmental practices, has implications for how these plans (and additional tools) could be developed in the future to improve communication between farmers and other actors in the transition to sustainable practices.

Keywords

boundary objects; environmental issues; multi-actor initiative; stakeholder groups; non-regulatory pressures; public perception

Introduction

Environmental sustainability and farm productivity are often regarded as antagonistic considerations which must be reconciled by farmers across agricultural industries. The dairy industry is a major industry in Aotearoa New Zealand, contributing 3.5% to Gross Domestic Product (GDP) in 2016 (New Zealand Institute of Economic Research 2017). At the same time, the dairy industry has contributed significantly to the on-going deterioration of water quality in rivers and lakes (Ministry for the Environment 2017). In recent years, public campaigns including campaigns by Fish and Game and Forest and Bird (Fish and Game 2018; Forest and Bird 2018) and policy measures, such as the National Policy Statement for Freshwater Management (Ministry for the Environment 2014) have been launched, aiming to improve water quality. These initiatives, along with increased public awareness of water quality issues, have brought attention to the effect of dairy farming practices on environmental health and dairy farmer’s Social License to Operate (SLO) is arguably being challenged (Foote et al. 2015; Edwards and Trafford 2016). Understanding how farmers navigate these challenges can inform organisations, including local government agencies, as to how they can support farmers and ultimately help facilitate a transition towards more environmentally sustainable farm practices.

This paper reports on research into how farmer practices are shaped in the context of a transition towards more environmentally sustainable agricultural land-use by exploring the following research question: how do farmers navigate pressures to adopt more environmentally sustainable practices? The research focused on how actors, their interactions and the local context were perceived to influence practices. This paper reports on interviews with members and key informants involved with a dairy farmer...
discussion group in Hawkes Bay, New Zealand, who have actively worked to mitigate the impact of their dairy farming practices on local water quality.

The Social Licence to Operate

To study changing expectations of what constitutes socially acceptable practices by industries or organisations, scholars have explored the concept of SLO (Edwards and Trafford 2016; Moffat et al. 2016). Most of the literature on SLO focuses on the mining industry, but the concept has also been applied to other sectors, including agriculture (Moffat et al. 2016). Social licence to operate is determined by the relationships between an industry and broader society and the social and legal licence to operate are not always aligned: approval on a regulatory level does not necessarily mean practices are socially acceptable (Shepheard and Martin 2008; Moffat et al. 2016). Social licence to operate reflects current societal values, expectations and perceptions and is negotiated and implied rather than acquired. Loss or compromise of the SLO can lead to conflict between the industry in question and the broader community (Moffat et al. 2016). Development and maintenance of SLO is a continuous and evolving process. Gaining and keeping SLO involves on-going negotiation between industry and society, during which industry practices must continue to be found justifiable (Shepheard and Martin 2008). For the New Zealand dairy industry, the SLO has been challenged, and it has been suggested that there is a need for farmers to communicate evidence of progress towards more environmentally sustainable farming practices, in order to retain SLO (Edwards and Trafford 2016). In other industries in which practices have been called into question (e.g. mining and oil industries), toolkits to engage with the community have been developed. These toolkits provide the mechanism to both demonstrate and communicate the alignment of practices with society’s expectations (Mercer-Mapstone et al. 2017).

Boundary Objects

“Boundary object” is a concept that refers to tools, ranging from documents to concepts, with the ability to enable communication between stakeholder groups. The concept was first introduced by Star and Griesemer (1989), who describe the use of boundary objects in their social study about the development of a museum in which people from different backgrounds needed to collaborate. Boundary objects emerge in their function as tools that connect stakeholder groups, and can vary in tangibility and flexibility (Klerkx et al. 2012). They can mean different things to different people, or groups of people. For instance, food labels have been described as boundary objects facilitating communication between the food industry and consumers (Eden 2011). Boundary objects can help identify and resolve disagreements between stakeholder groups, as well as identify areas of common ground. However, it is also important to consider the limitations of boundary objects. For example as, Tisenkopfs et al. (2015) highlights based on their research on empirical case studies examining the use of boundary objects in agricultural innovation; boundary objects can be more relevant to some stakeholders then others, or may lose their relevance to an issue over time. Boundary objects and SLO are both related to negotiations between people of different stakeholder communities who share an interest in the same “space”. Boundary objects can serve as a connecting tool that enables interactions between people to negotiate SLO.

Methodology

A qualitative single case study approach was used. The selected case is an example of a local response to a natural resource management issue. The criteria for the selection of the case included: that it was a multi-actor initiative aiming for sustainable land-use in Hawke’s Bay; and that the initiative has been active for at least three years. Based on these criteria, an existing farmer discussion group, run by DairyNZ (the national dairy industry good organisation) based in Hawke’s Bay region was selected. The farmer discussion group was based in an area that has recognised water quality issues. At the time of the interviews, the discussion group consisted of thirteen dairy farmers who met to discuss farming practices once a month, on one of their farms. Findings presented here originate from six in depth, semi-structured interviews with members of the farmer discussion group (individually or in two cases both partners), eight.
key informant interviews with people from industry and government organisations linked with the group, and the analysis of documents (including reports from local government agencies, webpages of the organisations involved and newspaper articles about the local water quality issue). All interviews were recorded, transcribed, digitally coded (in NVIVO) and thematically analysed (Coffey et al. 1996).

Navigating Expectations

In addition to regulatory pressures, all interviewed farmers expressed feeling pressure from their community, the wider public and the media to adopt more environmentally sustainable practices. There was a strong sentiment among farmers that the dairy farming industry and farmers received an unreasonable amount of scrutiny compared to other sectors. As expressed by one farmer about perceived differences between attitudes toward dairying and urban sewage overflow:

*But if we have a mistake we get in trouble, if we have a rain event like we had an inch of rain in 30 minutes and everything starts overflowing or anything like that we get in trouble, but if that happens in town and raw sewage goes into the sea or the lake or whatever that’s fine* [Farmer 1].

Additionally, farmers argued that the measures they were taking to reduce pollution are more effective than the more visible measures demanded of them by Fonterra (dairy corporative they belong to) through the Sustainable Dairying Accord, such as fencing streams and planting trees. So, farmers felt the need to defend their practices from notions they considered incorrect or unfair.

In response to these non-regulatory demands, farmers mentioned several ways in which they were actively trying to change perceptions through communication. Interestingly, the farmers in the farmer discussion group had collectively elected to develop Fonterra Farm Environment Plans (FEPs) for their farms, partly in order to demonstrate their efforts and progress regarding environmental stewardship. One farmer explained the purpose of the farm plans as follows:

*This is why we're pushing to get these farm environmental plans done so we've got them to take [to local community group meetings], so we've got evidence on it* [Farmer 2].

Initially the primary intention for creating the plans was not to act as a mechanism of communication to third parties, but to facilitate environmental planning and benchmarking. As a Fonterra sustainable dairying strategic team representative explained:

*[The plans were] more about our farmers understanding where they sat [with regard to environmentally sustainable practices] and how we could support them.*

The local community group in the catchment sought to incorporate the FEPs into catchment plans. Opportunities were identified to develop ways to integrate cultural and biodiversity values that the local community group felt were missing from the plans, and sought to align the FEPs with future objectives of the catchment plan. One local government employee expressed the following view:

*Some of the key areas that we don't see in the Fonterra plan... like the cultural section, the biodiversity, biosecurity section and... making sure that the farm plans are plugged into the integrated [catchment] plan.*

In addition to developing their FEPs, the farmer discussion group appointed farmer representatives to advocate for the dairy farmers at local community group meetings. Farmers saw the wider dairy industry, in particular milk processor Fonterra, as actively trying to improve public perceptions about dairy farming environmental responsibility, both locally and nationally. Farmers cited examples including investments in sustainable dairy advisors, creating their FEPs, TV commercials promoting industry environmental sustainability, and the ‘Clean Streams Accord’ as evidence of responsible, effective stewardship. Farmers had responded to regulatory pressures and other motivations by making changes on
farm, but during interviews the dairy farmers responses to negative perceptions and non-regulatory pressure reflected the need to communicate more effectively.

Discussion

In this study, farmers were found to navigate pressures to adopt more sustainable practices by seeking ways to communicate. This study identified differences in beliefs about what constitutes sustainable farm practices between the interviewed farmers and what they perceived the public believed. This difference drove farmers to seek to demonstrate and defend their practices. A parallel trend was seen by the participants in the wider industry, with industry organisations seeking to improve the industry’s environmental reputation. Therefore, in line with the work of Edwards and Trafford (2016), this empirical study suggests that dairying practices in New Zealand can be seen as an example where the SLO is being challenged. More specifically, farmers indicated that they were responding to regulations by adapting their practices, yet they felt further pressure from their community, the media and the wider public to adopt more sustainable practices. This can be described as an example of the legal and social licence not being aligned (Moffat et al. 2016) and different responses to each of them were observed.

In this case study perceived challenges to farmer’s SLO resulted in a mobilization of farmers who sought new ways to demonstrate their practices to their local community. The present study demonstrated that FEPs could act as boundary objects to communicate and demonstrate practices in the negotiation of SLO. The way the FEPs were used in the wider community was not anticipated or planned by the designers of these FEPs. Their use emerged because of a combination of local social and environmental circumstances. The FEPs were viewed and used differently by different stakeholder groups, and facilitated interactions that could be characterized as negotiations between these stakeholder groups. These attributes and uses of the FEPs are in line with what has been described in literature as boundary objects (Star and Griesemer 1989; Klerkx et al. 2012). Viewing FEPs as boundary objects is a novel way of viewing FEPs, which potentially broadens the scope of their application.

A practical implication of the observed use of FEPs as boundary objects in this case study is that future FEPs may be further developed to support this use. This could be achieved by adapting the language to non-farmer audiences and providing key summary information that could be easily understood. Additionally, in response to the demand of dairy farmers to demonstrate the sustainability of their practices and negotiate SLO, other tools could be deliberately designed to be used as boundary objects, as was done in the mining and oil industries (Mercer-Mapstone et al. 2017). However, as pointed out by Tisenkopfs et al. (2015), boundary objects also have their limitations, and careful consideration of the relevance of a boundary object to different stakeholder groups is important.

Conclusion

Evidence from this case study shows that FEPs were valued by farmers as a mechanism to communicate and make the sustainable practices farmers are implementing visible for people beyond their farms. Simultaneously, other actors saw opportunities to build on these plans. It is argued that FEPs are facilitating communication between stakeholders, shaping views and potentially contributing to a renegotiation of their SLO. Future research, including farmer surveys with greater participant numbers, will be needed to confirm whether this desire to communicate and demonstrate practices is shared by dairy farmers nationally. Considering the existing widespread application of FEPs among farmers in Aotearoa New Zealand, this novel way of viewing FEPs as boundary objects opens potential new uses of the plans for many farmers. As boundary objects, FEPs may enhance communication between farmers and their communities, and ultimately facilitate the negotiation of SLO.

References


Genetic gain in dry matter production of perennial ryegrass cultivars at two sites in Victoria

Agriculture Victoria, Department of Economic Development, Jobs, Transport and Resources,
255 Ferguson Road, Tatura, Vic. 3616, Australia.
AgriBio Centre, 5 Ring Road, Bundoora, Vic. 3083, Australia.
915 Mt Napier Road, Hamilton, Vic. 3300, Australia.
703 Raglan Parade, Warnambool, Vic. 3280, Australia.
Ellinbank Dairy Centre, 1301 Hazeldean Road, Ellinbank, Vic. 3821, Australia.

Corresponding author. Email: alister.lawson@ecodev.vic.gov.au

Short Title: Genetic gain in perennial ryegrass cultivars in Victoria

Abstract

The improvement in pasture dry matter (DM) production resulting from breeding of perennial ryegrass cultivars was quantified in two grazed experiments over three years. The experiments were sown in May 2014 using the same 36 treatments (PRG cultivar / endophyte combinations). Annual DM production over the three years averaged 6.4, 4.2 and 12.1 t DM/ha and 8.6, 16.6 and 12.3 t DM/ha at the south-west and the northern Victorian sites, respectively. At the south-west site there was no improvement ($P>0.05$) in DM production for the mid-season diploids released between the 1990s and the 2010s while there were improvements ($P<0.05$) for both the late-season diploids and tetraploids. There were no ($P>0.05$) systematic treatments effects on DM production at the northern site. Genetic gain calculated using the “frontier” approach was not evident at the northern site and was 0.21 % per year ($P=0.18$) at the south-west site. This finding suggests that published values of genetic gains in total DM production for PRG may not be consistently or fully realized, in environments that are marginal for PRG.

Additional Keywords: pasture

Introduction

Perennial ryegrass (PRG) (Lolium perenne L.) is the predominant forage species used in the Australian dairy industry. While there has been a long history of PRG breeding in the southern hemisphere, the genetic gain that has been achieved has not been clearly quantified in more marginal dairy environments such as south-west Victoria, which is characterized by a dry period from late-spring to mid-autumn, or northern Victoria where summer temperatures are high and irrigation is required to maintain PRG. In contrast, the rate of annual genetic gain for total yield in PRG has been estimated in both Europe (0.5% per annual, Wijk and Reheul 1991, and 0.35–0.52 %, McDonagh et al. 2016) and New Zealand (0.25–0.73%, Woodfield 1999, and 0.40%, Easton et al. 2002). A more recent estimate of annual gain in Australia and New Zealand, using a different methodology, estimated it at 0.76% (Harmer et al. 2016). However, these estimates reveal only the rate of gain in PRG when grown in monocultures and usually under mown and fairly ideal conditions.
The possible sources of genetic gain over time include gain within functional types \( (i.e. \) ploidy by maturity categories such as mid-season flowering diploids) and gain through broadening the range of functional types \( (e.g. \) into late-season flowering diploids and tetraploids). Broadening the range of functional types has potentially led to gains in DM production as cultivars with later flowering / heading have a less-pronounced spring peak of growth with more growth in late spring and summer, compared to mid-season flowering cultivars \( (Lee \textit{et al.} 2012).\)

This paper reports on research that, in 2 marginal environments, tested the hypotheses that: (i) PRG breeding since the 1970s has delivered gains in total pasture DM accumulation; and (ii) gains have come via improvements within functional types, and via broadening the range of functional types available.

### 1.44.1 Materials and Methods

The experimental sites were a dryland site at Terang \( (38°14'S, 142°55'\text{E}) \), in south-west Victoria and an irrigated site near Mooroopna \( (36°20'S, 145°17'\text{E}) \), in northern Victoria.

There were 36 treatments \( (\text{genotype} / \text{endophyte combinations}) \) \( (\text{Table 1}) \) that were replicated 4 times. Each site had a different randomisation. Plots were 4.2 m x 10 m in south-west and 3.6 m x 10 m in northern Victoria.

The sowing rate was 20 kg/ha for the diploid cultivars and 28 kg/ha for the tetraploid cultivars. All entries were sown as monocultures. Border areas were sown to 3 strips containing either cvv. Avalon, One50 or Bealey.

#### Site establishment and management

Both experiments were sown in early May 2014 and continued until May 2017. There were 17 grazings at the south-west and 39 at the northern site over the three years. All plots were grazed by dairy cows within 24 hrs down to a target residual rising plate meter \( (\text{RPM}) \) \( (Earle \text{ and McGowan 1979}) \) height of 5 cm. In south-west Victoria, grazing was targeted at a leaf stage of 2.5 to 3.0 from late autumn to early spring or when approximately 2500 to 2800 kg DM/ha was present. In northern Victoria grazing management was dictated by the farm owner, with the sward typically grazed at a leaf stage of 2.0 to 2.5. The grazing regimes were both close to recommended guidelines; the large difference in the number of grazings was mainly due to irrigation versus dryland, and was exaggerated by the low \( (60\% \text{ of average}) \) winter/spring rainfall in Year 2 at the south-west site. If the sites were inadequately grazed, the area was topped \( (\text{mown}) \) to a RPM height of 5 cm to minimise impacts of cultivar differences in grazing preference on herbage accumulation.

Nitrogen fertiliser was applied following grazing when moisture conditions were suitable, with a rate of 250 kg N/ha/year in northern Victoria \( (10 \text{ applications of 25 kg N/ha}) \) and of 133 kg N/ha/year in south-west Victoria \( (8 \text{ applications of 50 kg N/ha over the 3 years}).\)

#### Measurements

Pre-grazing, post-grazing, and if applicable, post-topping, pasture heights were measured using an Ellinbank RPM. Pasture DM production was derived from pasture heights using calibration equations.
generated for each of the three cultivars sown in the border areas of the experiments; these cultivars represented the 3 major functional types within the experiments.

**Statistical analysis**

The experimental design was a “resolvable Latinized 6 by 6 row-column design with 4 blocks and a nested treatment structure”. Data were analysed using linear mixed effects models fitted using restricted maximum likelihood (REML) in ASReml-R. For more details see Lawson et al. (2018).

The rate of genetic gain was determined using a modification of the Harmer et al. (2016) method in which DM production was plotted against the Year of Commercialisation. Cultivars were classified as “frontier” (defined at having DM production exceeding 90% of that of the best cultivar already on the market) or “also-ran” (the remaining cultivars).

**1.44.2 Results**

Pasture production averaged 6.4 (range 5.3-7.6), 4.2 (2.9-5.3) and 12.1 (10.4-14.8) t DM/ha for the south-west site and 8.6 (range 7.2-10.8), 16.6 (14.1-19.7) and 12.3 (9.8-16.1) t DM/ha for the northern Victorian site in Years 1, 2 and 3, respectively. The decade of release affected total DM production over 3 years at the south-west site (Fig 1), with 2010 releases exceeding \( P<0.05 \) those from the 1970, 1990 and 2010+ decades. This effect was also evident in Years 1 and 3 when winter/spring rainfall was >90% of the long-term average (lta) but not in Year 2 when winter/spring rainfall was 60% of the lta (data not shown). A similar analysis of the northern Victorian site showed no effect of decade of release on DM production (data not shown).

![Fig 1. Main effect of decade on total pasture production over 3 years at the south-west Victorian site. The number (n) of ryegrass / endophyte combinations within each decade is shown at the top of each column. The vertical error bars represent the average l.s.d. \( P=0.05 \) for the comparisons where the n values are (starting from the left), 1 vs 1, 1 vs 2, 4 vs 7, and 7 vs 7.](image)
The ploidy / maturity / decade (PMD) factor affected DM production for the south-west Victorian site with no difference ($P>0.05$) between the cultivars released in the 1990s, 2000s or 2010s for the mid-season diploids, while in the late-season diploids and tetraploids, the 2000 and 2010 releases performed better than the 1990 releases (Fig 2a). This effect was evident in each of the three years of the trial (data not shown) despite the 3-fold range in annual DM production. A similar PMD analysis for the northern Victorian site showed no differences ($P>0.05$) between any of the PMD factors (data not shown).

**Fig 2.** Main effect of ploidy / maturity / decade factors on pasture removed by (a) grazing and (b) topping, over 3 years at the south-west Victorian site. The number (n) of ryegrass / endophyte combinations within each factor is shown at the top in Fig (a). The vertical error bars represent the average l.s.d. ($P=0.05$) for the comparisons where the n values are (starting from the left), 1 vs 1, 1 vs 2, 2 vs 2, and 3 vs 3.

The DM removed by topping at the south-west site was greater ($P<0.05$) for the early-season diploids, particularly the 1940s cultivar, than from most of the later maturity types, and was greater ($P<0.05$) for the mid-season diploids than from the late-season tetraploids, with the late-season diploids being intermediate and not consistently different to either (Fig 2b). Relative treatment differences for total DM removed (grazed plus topped) and their statistical differences were similar to DM removed by grazing (data not shown).

The annual rate of genetic gain was $17\pm12$ kg DM/ha/year (0.21 % per year, $P=0.18$) at the south-west and $-4\pm18$ kg DM/ha/year ($P=0.83$) at the northern Victorian site.
1.44.3 Discussion

There was no evidence of an improvement in DM production for the mid-season diploids for the cultivars released between the 1990s and the 2010s while there was for an improvement for both the late-season diploids and tetraploids. However, this improvement in the DM production of the late-season diploids and tetraploids may be due to the poor performance of the 1990 releases rather than by the better performance of the later releases. In contrast, McDonagh et al. (2016) found improvements in all maturity classes for both diploid and tetraploid cultivars; this difference may be due to the longer time span (40 years) and greater number of cultivars (>200) in their work.

The amount of DM removed by topping was highest for the early- and, and to a lesser extent, the mid-season treatments. This could be a result of their growth characteristics such as a more pronounced spring peak of growth and worse nutritive characteristics during late spring (Lee et al. 2012) as well as to the fact that the early-season treatments represented a very small proportion of the total experimental site and so could have been preferentially not-grazed. While there were maturity/ploidy effects on the need for topping, the experimental setup used meant that it is not possible to be too definitive about the reasons for such treatment effects.

The rate of genetic gain at the south-west site was below the that reported by Harmer et al. (2016), whose methodology we adapted, or reported elsewhere in the literature in both Europe (Wijk and Reheul 1991, McDonagh et al. 2016) and New Zealand (Woodfield 1999, Easton et al. 2002). This finding could be for several reasons including the small number of treatments, the short time span over which the cultivars used in this study were released, and to the marginal environments, particularly in the second year at the south-west site. This finding suggests that the genetic gain for total DM production that has been reported in the literature may not be consistently and fully realized in marginal environments such as that encountered at the two Victorian sites.

1.44.4 Acknowledgements

We acknowledge Kevin Smith for the initial project development and DEDJTR technical staff at Warrnambool and Tatura for the establishment and conduct of the research.

We also thank PGG Wrightson, Heritage Seeds, Valley Seeds and David Chapman for the provision of seed, the staff of PGG Wrightson and Heritage Seeds who assisted with sowing the sites, and the Landholders for the provision of the land and their dairy herd.

This work was funded by the Department of Economic Development, Jobs, Transport and Resources and Dairy Australia.

The authors have no conflict of interest.

1.44.5 References


Table 1. Perennial ryegrass genotype / endophyte combinations sown in the experiment

<table>
<thead>
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<td>Quartet II Endo5</td>
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<tr>
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<td>HSPlp4 AR1</td>
<td>HSPlpt8 NEA2</td>
<td>KLp902 Endo5</td>
</tr>
</tbody>
</table>

¹ soon-to-be-released cultivars from the main seed companies to reflect where the industry is heading.
The effect of arginine or glutamine supplementation and level of milk allowance on small intestinal development in pre-weaning calves

P van Keulen*a,b, MA Khan*a, J. Dijkstra*b, FW Knol*a, and SA McCoard**

aAnimal Nutrition and Physiology Team, AgResearch Grasslands, Palmerston North 4442, New Zealand; bAnimal Nutrition Group, Wageningen University & Research, 6708 WD, Wageningen, the Netherlands

*Corresponding author. E-mail: sue.mccoard@agresearch.co.nz

Abstract

The objective was to evaluate the effect of 1% fortification of milk with arginine (Arg) or glutamine (Gln) at two levels of milk allowance (20% or 10% of arrival body weight) on the histomorphological development of the small intestine in pre-weaning calves. Sixty mixed sex Friesian x Jersey calves (3 days of age) were offered reconstituted whole milk powder (125 g/L, 26% fat, 26% protein) at either high or low milk allowance with or without Arg or Gln fortification in a 2 x 3 factorial design (n=10/group). Post-mortem small intestine samples were collected at day 35 for histomorphometric evaluation. The results indicate that Arg or Gln supplementation of milk enhances intestinal development through increasing the surface area at a high (6 g/d with high milk allowance) but not at a lower supplementation level (3 g/d with low milk allowance). Milk allowance alone had no effect on intestinal development. This may have important implications for feed digestion and nutrient absorption, and subsequently calf performance. Furthermore, Arg and Gln supplementation had a positive effect on goblet cell numbers independent of milk allowance indicating improved intestinal integrity and potentially pathogenic defence barrier which may be beneficial for calf health.

Keywords

calf nutrition; L-arginine; L-glutamine; feeding level; intestinal development

Introduction

The gastrointestinal tract is an organ system crucial in feed digestion, nutrient absorption and protection against external pathogens. In this respect, changes in the structure of the small intestine (SI) in pre-ruminant calves are particularly important because it is the primary site of digestion and absorption of milk (Blum 2006). Increasing milk allowance enhances pre-weaning growth, but suppresses solid feed intake before weaning and, therefore, delays rumen development (Khan et al. 2016). In contrast to the rumen, the effect of increased milk intake on SI development in calves is largely unknown (Steele et al. 2016).

Arginine (Arg) and Glutamine (Gln) are conditionally essential AA for the growth of neonates (Wu 2009). In addition to the role Arg plays as a building block for protein synthesis, it is also a common substrate for nitric oxide and polyamine synthesis, thereby fulfilling a key role in intestinal cell proliferation (Tan et al. 2010). In neonatal piglets, supplementation of Arg increases the intestinal absorptive area (Wang et al. 2012; Xu et al. 2012). Furthermore, Gln is used by enterocytes as a source of energy as well as for the endogenous synthesis of Arg (Wu 2009). Dietary Gln-supplementation enhances villus growth (Jiang et al. 2009) and
reduces the severity of villus atrophy due to diarrhea in weaned pigs (Wu et al. 1996). The effect of Arg or Gln on SI development in calves, however, is unknown. The objective of this study was to determine the effect of dietary Arg- or Gln-supplementation at two levels of milk allowance on SI development in pre-weaning calves.

**Material and Methods**

This study was reviewed and approved by the Animal Ethics Committee of AgResearch Grasslands (Approval #13831). Sixty mixed-sex Friesian×Jersey calves (4 ± 1.1 d) were sourced from two local commercial farms, weighed and randomly allocated to six treatments in a 2×3 factorial design (n=10/treatment). Mean arrival body weight (BW) was 29.3 ± 0.64 kg, and was similar among the treatments. Calves were individually fed whole milk powder (26% CP, 26% fat; NZAgbiz; mixed at 125 g/L) using automatic-feeders (CalfSmart, NZ). Calves were either offered a control diet without supplementation at low milk (LM; 10% of arrival-BW/d) or high milk (HM; 20% of arrival-BW/d) allowance or with supplementary L-Arg or L-Gln (Merck NZ). The amino acids were included at 1% of milk DM (i.e., calves were offered 3.0 or 6.0 g/d in LM-Arg/LM-Gln and HM-Arg/HM-Gln, respectively). Pelleted calf starter (22% CP; SealesWinslow) and water were offered ad libitum.

Animals were slaughtered at 35 ± 2.4 d of age and duodenum, jejunum, and ileum samples were collected, fixed in formalin, and processed by the Histology Laboratory of Massey University (Palmerston North, NZ). In short, the tissues were dehydrated through graded alcohol baths, embedded in paraffin, and 4 μm thick sections were stained using the haematoxylin-eosin method. Morphometric analysis involved villus height, width, and density, whereupon the total absorptive surface area was calculated according to Kisielinski et al. (2002). Villus height (VH) and crypt depth CD) were measured and VH:CD ratio calculated, and goblet cells were counted. Analysis was performed using a light microscope coupled with a digital camera (ProgRes C14, Jenoptik) to a computer with image processing software (Image-Pro 7.0, Media-Cybernetics).

Intestinal response variables were analysed using a linear mixed model (R Core team 2017) with main and interaction effects of dietary treatment factors (AA supplementation and milk allowance level) as fixed effects and calf parameters (sex and farm source) as random effects. Values are presented as LS means ± SEM and effects were significant at P≤0.05.

**Results and Discussion**

There was an interaction (P<0.01) between milk volume and AA supplementation whereby duodenal and jejunal absorptive surface area was increased (P<0.01) in HM-Arg/HM-Gln calves by 63/40% and 36/45%, respectively (Fig. 1), compared to all other groups which in turn did not differ. Furthermore, there was no treatment-effect on ileal morphology. Villus growth and absorptive surface area of the intestinal epithelium are important parameters in increasing intestinal nutrient absorption to support calf growth. Our observations on Arg- and Gln-supplementation in the HM groups (i.e. at the higher level of AA supplementation of 6 vs 3 g/d) are consistent with the positive effect of supplementary Arg (0.6% of milk DM) on villus development, particularly in the duodenum and jejunum, reported in milk-fed neonatal piglets (Wang et al. 2012; Xu et al. 2012). Furthermore, Wu et al. (1996) and Jiang et al. (2009) showed that the supplementation of 1% Gln of milk DM prevented jejunal atrophy in diarrheic pigs. In this experiment, supplementary Arg or Gln intake of 1% of milk DM, only at a higher milk intake, resulted in a positive effect
on villus growth. The absence of an effect of milk volume per se on villi development suggests that the increase in absorptive surface area in the HM-Arg and HM-Gln but not the LM-Arg and LM-Gln groups is a response to the greater intake of the supplemented AA. While a full dose response study has not been conducted in calves, these results provide initial insight into the potential dietary concentration required to elicit a positive effect on villi development.

![Fig. 1. Intestinal surface area of 35-d-old pre-weaning calves fed a non-supplemented control diet or supplemented (at 1% of milk DM) with arginine (+Arg) or glutamine (+Gln) in combination with a low (10% BW/d; LM) or high milk allowance (20% BW/d; HM). Values with different superscripts differ significantly (P≤0.05).](image)

New intestinal cells form in the base of the crypt and migrate up along the epithelial surface to the top of the villus. Thus, an increased VH:CD ratio is an indicator of enhanced intestinal cell proliferation and/or reduced cell apoptosis (Tan et al. 2010). Therefore, the interaction between AA supplementation and milk volume with a greater VH:CD ratio observed in the duodenum of the HM-Arg calves relative to all other groups (P<0.01), and in the jejunum of the HM-Arg and HM-Gln calves relative to HM-Ctrl calves (P=0.04), is indicative of greater intestinal cell growth/proliferation and/or reduced apoptosis in response to Arg (duodenum) and to Arg or Gln (jejunum) at the higher supplementation level (Table 1).

Goblet cells are intestinal mucins secreting cells creating a physical barrier at the mucosal surfaces of the intestine, which serve as the front line of innate host defence (Kim & Ho 2010). Similar to other intestinal epithelial cells (Tan et al. 2010), goblet cells may also depend on Arg, Gln, and their metabolites for proliferation and differentiation. An interaction between AA supplementation and milk feeding level on the number of duodenal goblet cells was observed where Arg increased (P<0.01) and Gln tended to increase (P=0.08) the number of jejunal goblet cells compared to controls, regardless of milk allowance (Table 1). These results are similar to the results of Wu et al. (2010), where dietary Arg-supplementation increased the number of goblet cells throughout the SI of pigs.

**Table 1.** Small intestinal histomorphology of 35-d-old pre-weaning calves fed a non-supplemented control diet or supplemented (at 1% of milk DM) with arginine (+Arg) or glutamine (+Gln) in combination with a low (10% arrival BW/d) or high milk allowance (20% arrival BW/d).
The effect of supplementation (S), milk allowance (M) and their interaction (S × M) are presented. 

a, b, c Values within a row with different superscripts differ significantly (P≤0.05).

In summary, the results indicate that Arg- or Gln-fortification of milk enhances intestinal development through increasing surface area when supplemented at 1% in milk diets offered at a greater allowance (20% of BW), but not at lower level milk allowance (10% of BW). Furthermore, milk allowance alone had no effect on intestinal development. This may have important implications for feed digestion and nutrient absorption, and subsequently calf performance. Furthermore, the positive effect of Arg- or Gln-supplementation on goblet cells is important for intestinal integrity and potentially improving the pathogenic defence barrier and calf health.

Acknowledgements

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References

Predicting Climate Change Impacts for Dairy in New Zealand and Australia

Ross Abercrombie¹, Nick Sneddon¹, Mike Scarsbrook¹, Berit Arheimer² and Lorna Little²

¹Fonterra Research and Development Centre, Private Bag 11-029 Palmerston North, Fonterra Co-Operative Group Ltd, ²Swedish Meteorological and Hydrological Institute, SE-601 76 Norrköping, Sweden

Short title: Climate impacts on Dairying Regions

Abstract
Climate change poses a significant challenge to dairy farming systems. Adaptation to predicted changes will be enhanced with improved modelling of regional changes in climate indicators. In this study, we use a Multi-Model Ensemble (MME) approach, using output from a suite of eighteen global climate models to predict impacts of climate change on rainfall and temperature variables across major dairying regions in New Zealand and Australia. Rainfall was predicted to increase across New Zealand dairying regions and decline across Australian regions, apart from Tasmania. Temperature across all regions increased, with fewer frost days and more tropical nights. This could increase pasture production across New Zealand regions, but comes with increased challenges for feed production in Australian regions.

Keywords
Climate Change, Global climate modelling, Dairy, New Zealand, Australia

Introduction
Agriculture is facing multiple drivers for change with climate change arguably the greatest challenge for the next generation of farmers. Climate change will affect precipitation and temperature patterns, with potentially far-reaching consequences for farm systems. These changes will vary regionally and could lead to fundamental shifts in land use patterns. Improving our understanding of likely climate changes at regional scales will help the agriculture sector prepare for the transformation to come.

Mitigation of GHG emissions attracts significant research funding and attention from governments, whereas climate change adaptation has received far less attention (Harrison et al. 2017, Kalaugher et al. 2017). There have been several studies in New Zealand and Australia describing effects of climate change on agriculture (e.g. Cullen et al. 2009; Tait et al. 2008; Keller et al. 2014). These studies have tended to use climate change predictions from 1-2 global climate models, where confidence in future trends can be very uncertain. In this study, we use a Multi-Model Ensemble (MME) approach, using output from a suite of eighteen global climate models to predict impacts of climate change on rainfall and temperature variables across major dairying regions in New Zealand and Australia.

Methods
The Copernicus Climate Change Service (C3S; https://climate.copernicus.eu/) is developing information services that deliver climate impact indicators (CIIs) to assist users from different sectors in climate change adaptation. The core of the global service is a suite of CIIs from 18 global climate models (GCM) (bias adjusted and downscaled to 0.5 degree resolution) and a Climate Data Store that houses a vast array of primary and secondary climate and environmental data. Fonterra has been an international end-user in the C3S project and is using the service to increase awareness and understanding of likely impacts of climate change across multiple geographies where we collect milk.
The modelled results of two future climate scenarios (Representative Concentration Pathway (RCP) 4.5 and RCP 8.5; IPCC 2013) on values of five Climate Impact Indicators (Mean and Maximum Temperature, Number of Frost Days (number of days when daily minimum temperature is below 0°C), Number of Tropical Nights (number of days when daily minimum temperature is above 20°C) and Mean Daily Precipitation) were accessed from the C3S Global Service. Indicators were calculated based on monthly data over four periods: Historical (1970-2000), 2011-2040; 2041-2070 and 2071-2100.

We chose the following regions as representative of major dairy production areas: Northland, Waikato, Taranaki, Canterbury, Southland, N Tasmania, N, SE & SW Victoria (Fig. 1). For each region, a 1 x 1 degree box was identified, and results from the C3S global model ensemble model were downloaded for nine points within these boxes (i.e. 3 x 3 array of points based on 0.5 degree model resolution). Means of these nine points were used to generate regional statistics for each indicator and ensemble model. MME averages were then calculated to reduce observed inter-model variability to a central tendency prediction.

![Figure 1. Dairying regions included in climate impact indicator modelling.](image)

**Results**

The C3S Global Service Multi-Model Ensemble predicted mid-century increases in mean annual rainfall in all five of the New Zealand regions (Table 1) under the most pessimistic climate scenario (RCP 8.5). In contrast, all four Australian regions were predicted to have reductions in mean annual rainfall (-5 to -11%).

The other four Climate Impact Indicators showed consistent trends in all nine regions, although the magnitude of change varied significantly. All nine regions were predicted to show increases in mean daily temperature and mean daily maximum temperature, with Canterbury, Tasmania and Southland all exhibiting increases of more than 20% for MDT relative to 1970-2000 and >14% for MDMT.

Total tropical nights (nights where temperature remains over 20 °C) showed the greatest magnitude of change of any of the indicators (average across all regions of >1000%). Taranaki and Canterbury had the greatest predicted changes (>2000% increase Canterbury from 0.2 to 15 tropical nights, Taranaki increased from 0.5 to 32 tropical nights), whereas relative changes in Australian regions were generally an order of magnitude lower.
Total frosts days showed consistent and large decreases in all nine regions (average = -87%). However, the range of changes was quite narrow across regions (-157% in Northland to -70% in Southland).

Table 1. Relative changes in Climate Impact Indicators by region for mid-century (2041-2070) projections relative to historical averages (1970-2000)

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<tr>
<th>Measure *</th>
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<tr>
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<td>11%</td>
<td>13%</td>
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<td>15%</td>
</tr>
</tbody>
</table>

*MAR = Mean Annual Rainfall, MDT = Mean Daily Temperature, TTN = Total Tropical Nights, TFD = Total Frost Days, MDMT = Mean Daily Maximum Temperature; RCP = Representative Concentration Pathway; HA = Historical Average.

Discussion

Overall, the mid-century (2041-2070) predictions were for warmer mean and maximum temperatures, dramatic increases in tropical nights and significant decreases in frost days across key dairy regions of New Zealand, Victoria and Tasmania. Mean annual rainfall was predicted to increase for five New Zealand regions, but decrease for the four Australian regions.

There have been few published studies investigating the implications of climate change for dairy production. Cullen et al (2009) identified that higher temperatures and reduced rainfall in southern
mainland Australia, will lead to small increases in feed production by 2030, but decreases of up to 19% by 2070. However, their modelling also predicted pasture production in northern Tasmania was likely to be more resilient to climate change. Keller et al (2014) suggested that high-fertility systems such as dairying could be more resilient than drystock under future change, with dairy production increasing or only slightly declining in all their scenarios. Tait et al (2008) predicted average year pasture production and worst year production declines for east coast locations in New Zealand and Northland, but improvements in production for Southland and the West Coast – regions which are projected to remain moist while warming.

In a recent study, Chang-Fung-Martel et al (2018) highlighted climate challenges for animal health and welfare include increasing heat stress. Increases in total tropical nights and mean daily maximum temperatures suggest the need for increased research on mitigating impacts of heat stress on animal welfare and production. In addition, the reductions in frost days will increase survival of pest species and this will need to be factored into pastures, and animal health and welfare effects.

The current assessment is preliminary and more detailed analyses of regional effects of climate change on milk production and animal welfare (e.g. heat stress) are underway. These assessments will aid climate risk mitigation across Fonterra’s business.

References
Abstract

This study was conducted to investigate the effect of heat stress (HS) event on cow milk production at different stage of lactation (SOL) in summer. Daily milk production data were collected from a Robotic Milking System between 1 and 18 February 2017 from cows differing in their SOL: 16 cows calved in January 2017 (early SOL), 70 cows calved in August-September 2016 (mid SOL), and 23 cows calved in April-May 2016 (late SOL). Milk production records over 7 days prior to the beginning of a 4 days HS event (8-11 February 2017 with a mean temperature humidity index above 72, and maximum above 82) was used as a baseline data to quantify the milk production reduction. The late SOL and mid SOL groups decreased milk production by 17% and 15%, respectively during HS event with milk production recovering by 7 days after the HS event. Milk production of early SOL group increased at a rate of 2.2 kg/day prior to the HS event, slowing down to 0.17 kg/day during the HS event before recovering to 0.79 kg/day after the HS event. This study provides quantitative data on the interactive effects of HS and SOL on dairy cow milk production in summer.

Keywords
Robotic milking; grazing systems; voluntary movement; season

Introduction

Milk production performance of lactating cows is optimum within the zone of thermoneutrality with an upper limit of ambient temperature around 26°C for Holstein cattle (Berman et al., 1985). Above this upper critical ambient temperature, the ability of lactating cows to dissipate heat is compromised and cows start to experience heat stress (HS). In this case, several physiological and behavioral responses are initiated to maintain body thermal balance such as reducing feed intake (Kadzere et al., 2002). Decline in feed intake combined with increased maintenance requirements to assure thermal balance normally results in a negative energy balance that leads to declines in milk production (Wheelock et al., 2010). Though, the nutritional-metabolic conditions and energy balance of lactating cows are related to their stage of lactation (SOL) and several studies investigated the effect of SOL interaction with HS under controlled climatic conditions (Maust et al., 1972; Johnson et al., 1988), little is known about the interactive effect of SOL and HS on cow performances in pasture grazing based automatic milking systems (AMS) with voluntary cow movement. This study aimed to investigate the effect of SOL on cow milk production in a grazing system under hot and dry climatic conditions in Victoria, Australia.
Materials and Methods

Data collection

Individual cow data were collected from the dairy farm at Dookie Campus, The University of Melbourne, in Victoria, Australia. The farm consists of 43 ha of irrigated pastures and a milking herd of 155 Holstein-Friesian cows. Cows are milked in a Lely Astronauts AMS, with voluntary cow movement through three grazing areas to facilitate a target milking frequency of three times per day per cow. The data comprised individual daily records of milk production from September 2016 to May 2017. Cows data were grouped into 3 calving groups according to their calving period: “spring” (August-September 2016 calving), “summer” (January 2017 calving) and “autumn” (April-May 2016 calving) (Figure 1).

Meteorological data were obtained from the weather station using ADCON Telemetry (Klosterneuburg, Austria) at Dookie Campus and consisted of measures of ambient temperature and relative humidity (RH) at 15 minute intervals. The Temperature Humidity Index (THI) was calculated using the following formula (Little and Campbell, 2008):

\[ THI = T_{db} + 0.36 \times T_{dp} + 41.2 \]

where \( T_{db} \) = dry bulb temperature (°C) and \( T_{dp} \) = dew point temperature, derived from \( T_{db} \) and RH using Heinrich Gustav Magnus-Tetens’ formula.

\[ T_{dp} = (b \times T_{db}, RH)/(a - \gamma(T_{db}, RH)) \]

where:

\[ \gamma(T_{db}, RH) = (a \times T_{db})/(b + T_{db}) + \ln(RH/100) \]

\[ a = 17.27 \]

\[ b = 237.7 \]

For each day, 3 THI-related variables (maximum, minimum and average THI) were calculated. The critical THI threshold of 72 for milk production (Du Preez et al., 1990; Little and Campbell, 2008) was used to identify potential HS periods during the study period. A period of HS with milder weather conditions either side was selected for analysis. The HS event selected (daily average THI above 72 and a maximum THI above 82) was for 4 consecutive days, from 8 to 11 February 2017 (Figure 2). Milk records over 7 days prior to the HS event were used as a baseline data. Cows from summer, spring and autumn calving groups were respectively in their early SOL (1-30 days), mid SOL (118-182 days) and late SOL (>270 days) during the HS study period. The mid, early and late SOL calving groups were composed of 70, 16 and 23 mixed parity cows, respectively.

Data analysis

In the study, individual cow was repeated measured for their milk production. The data were analysed by a mixed effects model with covariate of parity, fixed effects of calving group, date and their interaction, and random effect of cow. For significant interaction of calving group and date (P < 0.001), the predicted mean of three SOL at each date were produced from the fitted model, and multiple comparison of these means with P value adjusted by Benjamini & Hochberg method were further generated. An average least significant difference (LSD) bar was shown on Figure 1 at significant level of 0.05. The whole analysis was performed by package ‘lme4’ and ‘predictmeans’ in statistical software R 3.5.1 (R Foundation for Statistical Computing, https://www.r-project.org/foundation/).

Insert Fig 1, 2 about here
Figure 1. The effect of stage of lactation on milk production performances of cows grazing pasture under heat stress conditions (8-11/February/2017) with average LSD bar at significant level of 0.05.

Figure 2. The daily average temperature humidity index (THI) calculated for experimental period.
Results

By the end of the 4-day HS event, the late and mid SOL groups had decreased milk production by 17% and 15%, respectively compared to their baseline period (Figure 1). The late and mid SOL groups recovered their milk production level to the baseline period 5 and 7 days post the HS event. Milk production of early SOL group increased at a rate of 2.2 kg/day prior to the HS event (1-7 February 2017), and then slowed down to 0.17 kg/day during the HS event (8-11 February 2017) before recovering to 0.79 kg/day post the HS event (12-18 February 2017) (Figure 1).

Discussion

The study demonstrated a strong effect of SOL on milk yield change in response to HS. The typical milk yield decline during a HS event and recovery to the pre HS event level within a week was also observed in previous studies (Dunshea et al. 2013; Garner et al. 2017). Cows from early SOL produced more milk than the mid and late SOL groups, which is in agreement with findings from Maust et al. (1972). This may be partly explained by the milk production in early SOL cows is supported by tissue mobilization and less by feed intake, compared with mid and late SOL cows (Bernabucci et al., 2010). Moe et al. (1971) showed that the metabolic utilization of tissue stores has a higher efficiency compared to the metabolic utilization of feed. This suggests that early SOL cows should produce less metabolic heat per kg of milk yielded than mid and late SOL cows, and thus, result in less sensitive to HS event. However, it is difficult to assess the sole impact of HS on early SOL cows in this study, because the actual increase of milk production and rate of increase in early SOL are also contributed by the change of feed intake and body energy mobilization, which both were not quantified in this study. Further work is needed to understand the impact of consecutive HS events impact on cows with different SOL.

Conclusion

The study provided quantitative data of the interactive effect of HS and SOL on cow performance. Late and mid SOL groups had a milk production decline during the heatwave, and recovered within a week. Milk production of the early SOL group did not decline during the HS event, but slowed down its rate of increase. Further work is needed to understand the impact of consecutive HS events impact on cows with different SOL.

Acknowledgments

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References


Profit variability in dairy systems with differing feed bases and supplement use – a Northland case study

KS McCahon1*, OK Spaans2, M Neal3, CJ Boom2, GJ Doole1, and JR Roche1,3,4
1DairyNZ Limited, Newstead, Private Bag 3221, Hamilton 3210, New Zealand.
2AgFirst Northland Limited, 51 Norfolk Street, Regent, Whangarei, Northland 0112, New Zealand.
3School of Biological Sciences, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand.
4Ministry for Primary Industries, PO Box 2526, Wellington 6140, New Zealand.

*Corresponding author. Email: kieran.mccahon@dairynz.co.nz

Abstract

The use of supplementary feed can be an effective strategy to reduce production risk, although it simultaneously increases costs and exposure to market risk. As a result, despite the greater milk production that can be achieved by importing supplementary feed, farm profitability may not be improved. We compared three treatments differing in stocking rate and the nature of feed supply on one research farm over three years. In the Pasture treatment, the herd’s diet consisted entirely of pasture grown on farm, including conserved pasture silage. This was compared with two treatments offering additional feed in the form of forage crops grown on farm or ‘imported’ palm kernel extract (PKE). A Monte Carlo analysis was conducted to compare profit for each treatment and associated variability over a range of market conditions. Across the three production years explored, when accounting for the likely variability of milk and input prices, and with high responses to supplement, operating profit was, on average, greatest with the PKE treatment.

Introduction

The balance between feed supply and demand within pasture-based systems is driven by pasture growth. Growth is subject to both inter- and intra-annual variation, predisposing pastoral systems to considerable production risk (Chapman et al., 2013). When pasture growth is insufficient, farmers may use supplementary feed to reduce this element of production risk, depending on their attitude to risk. Within the last decade, there has been a large increase in the use of imported feedstuffs in dairy production systems in New Zealand (DairyNZ Ltd, 2018). This change has increased unit milk costs and exposed farm businesses to a greater degree of market risk. The profitability of feeding imported supplement is dependent on market conditions (milk and supplement prices) and the marginal milksolid response to supplement that is achieved. The objective of this study was to determine the relative financial performance of three different farm systems under variable market conditions.

Materials and methods

Trial methodology
A three-year, farm systems trial was conducted from 2015-2018 on the Northland Agricultural Research Farm (NARF) (35°56′39″S 173°50′34″E). Paddocks were blocked into groups of three and randomly allocated to one of three treatments: “Pasture”, “Cropping” and “PKE”. At the beginning of the trial, each farmlet (28 ha) was balanced for pasture cover, soil type and proportion of kikuyu in the sward. Two-hundred and twenty-two Jersey-Friesian cross cows were randomly allocated to the Pasture (n= 70; 2.5 cows/ha), Cropping (n= 76; 2.7 cows/ha), and PKE (n= 76; 2.7 cows/ha) treatments. Ethics approval was obtained from the Ruakura Animal Ethics Committee. The realised stocking rate varied between years in response to feed availability as affected by climatic events.

Within the Pasture treatment, the herd’s diet comprised entirely of pasture grown on farm (grazed in situ or conserved and fed as silage). In the Cropping and PKE treatments, additional feed was available in the form of forage crops grown on-farm and imported PKE, respectively. On average, 23%(22-25%) of the cropping treatment was planted annually in forage crops including turnips, fodder beet and maize. Within the PKE treatment, PKE was offered when the post-grazing residual was less than 4 cm (~1,600 kg DM/ha). The greater stocking rate on the PKE and Cropping treatments was a reflection of a greater feed supply.

Economic modelling

@Risk software (Palisade, 2017) was used to assess and compare profit and its variability for each of the three treatments. @Risk is a tool for performing Monte Carlo analysis that allows key input variables to be modelled as a distribution to determine the likely variation in output variables. Operating profit was calculated for each treatment from the financial outputs of the trial. Distributions were incorporated for key input variables, specifically milk price ($/kg milksolids, MS), PKE price ($/tonne), urea fertiliser price ($/tonne) and grass silage price ($/t DM) to determine potential variation in operating profit (adjusted for differences in capital requirements) for each treatment. Correlations between these input variables were also included in the analysis, as specified by Neal and Cooper (2016). A Monte Carlo analysis consisting of 10,000 potential scenarios (iterations) was performed to generate cumulative probability density functions (CDF) for each treatment; these detail the likely distribution of operating profit. Although there were three years of data, carry-over effects (e.g., conserved feed inventory) existed between seasons resulting in a lack of independence between production years. Therefore, three-year mean operating profit was calculated for each treatment. The results obtained, therefore, present the relative medium-term profitability for the three given production seasons over a range of potential milk and input prices.

Results and discussion

Milksolids production (kg MS/cow and kg MS/ha) was greater with the PKE treatment, relative to both the Pasture and Cropping treatments (Table 1), as a result of more days in milk (DIM) and greater daily milk production. There were no significant differences between treatments for any of the reproductive outcomes measured (Table 1).
Table 1: Biophysical results

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Pasture</th>
<th>Cropping</th>
<th>PKE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocking rate (cows/ha)</td>
<td>Mean</td>
<td>sd(^2)</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
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<td>2.7</td>
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<tr>
<td>Lactation length (d)</td>
<td>262</td>
<td>13</td>
<td>268</td>
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<tr>
<td>Milksolids production</td>
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<td></td>
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<tr>
<td>Kg MS/cow</td>
<td>359</td>
<td>19</td>
<td>367</td>
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<tr>
<td>Kg MS/ha</td>
<td>915</td>
<td>43</td>
<td>997</td>
</tr>
<tr>
<td>Supplement offered (kg DM/cow)</td>
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</tr>
<tr>
<td>Silage</td>
<td>368</td>
<td>183</td>
<td>63</td>
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<tr>
<td>Maize</td>
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<td>0</td>
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<tr>
<td>Fodder beet</td>
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<td>Turnips</td>
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<td>0</td>
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<td>PKE</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
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<td>183</td>
<td>1097</td>
</tr>
<tr>
<td>Nitrogen (kg N/ha per year)</td>
<td>177</td>
<td>44</td>
<td>162</td>
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<td>3 week submission rate (%)</td>
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<td>9</td>
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<td>Non-return rate (%)</td>
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<td>74</td>
</tr>
<tr>
<td>Empty rate (%)</td>
<td>8</td>
<td>2</td>
<td>11</td>
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</table>

\(^1\)Pasture treatment herd fed pasture grown or conserved on farm. Cropping and PKE treatment herds offered forage crops grown on farm and PKE respectively, in addition to pasture grown on the farmlet.

\(^2\)sd: Standard deviation across three years

The results of the Monte Carlo stochastic analysis are displayed in Figure 1, as a CDF. If a CDF lies entirely below and to the right of another, the treatment yields a preferable outcome in every probability level, and is said to be stochastically dominant in the first degree. If the CDFs cross, neither treatment is preferable across every outcome. However, second degree stochastic dominance may be established if a
treatment has a greater minimum operating profit and the advantage of selecting the treatment relative to another outweigh the disadvantages (Hardaker et al., 2015).

The Cropping treatment was first order stochastically dominated by the PKE treatment and second order stochastically dominated by the Pasture treatment (Figure 1). No stochastic dominance existed between the Pasture and PKE treatments; therefore, a decision maker’s preference between the Pasture and PKE treatments depends on their degree of risk aversion when facing market volatility. The PKE treatment performed better in approximately 70% of the scenarios and, on average, returned a greater operating profit than the Pasture treatment. However, the cases in which the Pasture treatment outperformed the PKE treatment occurred when operating profit was low or negative. Therefore, a particularly risk averse decision maker may favour the Pasture treatment, as it minimises the loss in extremely unfavourable market situations (e.g. low milk prices and high supplement costs). Despite this, the net potential economic advantage of the PKE treatment relative to the Pasture treatment in favourable market conditions outweighs the net disadvantage in unfavourable market conditions. For a decision maker with low to moderate risk aversion and manageable debt levels, the PKE treatment would likely be their
preferred system. However, the marginal milk production responses to supplement achieved across the three years of the trial (data not presented) were consistently 30-50% greater than published results (Bargo et al., 2003), the reasons for this are under further investigation. The financial performance of the PKE treatment relative to the Pasture treatment was dependent on these high responses.

Conclusions

The biophysical results of this study demonstrate the benefit of feeding imported supplement within grazing systems to reduce production risk. In contrast cropping did not reduce production risk under the trial conditions experienced. Over the three production years analysed, when accounting for probable variation in milk and input prices, a farm system incorporating a proportion of herd intake as imported supplementary feed, on average, provided a greater operating profit, compared with a pasture-only system. This is dependent on the marginal milk production response to supplement, which under the conditions investigated here was greater than published results.

Acknowledgements

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Effects of cow milking order on access to pasture and milk production in an automatic milking system

Brendan Cullen1*, Hsiu-Ming Weng1, Jeremy Desfreres2 and Long Cheng1

1Faculty of Veterinary & Agricultural Sciences, The University of Melbourne, Victoria 3010, Australia
2AgroParisTech, Paris Institute of Technology for Life, Food and Environmental Sciences, France.
*Corresponding author. Email: bcullen@unimelb.edu.au

Abstract

Little is known about the consistency of milking order in automatic milking systems (AMS) with voluntary cow movement and how this can influence the characteristics of pasture on offer to cows in the herd. This study utilized cow records from a split-calving herd of 156 dairy cows in a pasture-based AMS in Victoria during November 2017 to establish the milking order and its relationship with milk production. In addition, pasture mass and quality were measured every 2 hours during the morning grazing on 28-29 November 2017 and used in GrazFeed to predict the effects of changing pasture characteristics on milk production. Milking time records demonstrated that there were groups of approximately 20 cows that were consistently ‘early’ or ‘late’ in the milking order. Average energy corrected milk production of ‘early’ and ‘late’ cows was 36.4 and 29.3 kg/day, respectively. ‘Early’ cows entered the pasture at an average mass of 3,250 kg DM/ha and consumed pasture with 10.4 MJ Metabolizable Energy (ME)/kg DM, while ‘late’ cows entered at 1,850 kg DM/ha and consumed pasture with 9.9 MJ ME/kg DM. GrazFeed modelling of cows in early lactation consuming 7.6 kg DM/day pellets and offered pasture with the average mass and DMD at time of entry of ‘early’ and ‘late’ cows, predicted that ‘early’ cows would produce 2.1 kg/day more milk than ‘late’ cows (31% of the measured difference). This research highlights the important role that the interactions between pasture characteristics and cow grazing behavior play in determining milk production from animals within the herd.

Introduction

On most Australian dairy farms, cows obtain the majority of their energy requirements from pasture (Jacobs 2014). Pasture is generally offered to the herd in a rotational grazing system with two or three allocations per day, usually after milking, with the pasture being consumed by the herd over a period over several hours. It is well established that cows can maximize bite mass and pasture intake rate with a higher sward herbage mass (Barrett et al. 2002). Additionally, pasture nutritive characteristics change with sward height, with protein and metabolizable energy levels being higher at the top of the sward and declining down through the canopy (Delagarde et al. 2000; Cullen et al. 2017). Thus, cows that enter the pasture early in the grazing allocation are advantaged because they can maximize pasture intake rate and select pasture with higher nutritive value. By contrast, cows that enter the pasture later will be limited in both aspects, and these differences may have important implications for milk production. Beggs et al. (2017) showed that milking order in pasture-based dairy systems is quite consistent even in large herds, particularly at the start (‘early’) and end (‘late’) of milking. These ‘early’ cows tend to have higher milk production than ‘late’ cows (Scott et al. 2014), but the extent to which this difference in production is
related to access to pasture, or other factors such as genetic or behavioural differences, is not known. The aim of this research was to determine (1) the consistency of milking order in a pasture-based system where cows move voluntarily between pasture and the milking parlour; (2) how pasture mass and nutritive characteristics change during a grazing allocation; and (3) how different pasture characteristics will impact in the milk production of cows that are early or late in the milking order.

Materials and Methods

Dairy farm system

The experiment was conducted at The University of Melbourne, Dookie campus robotic dairy in northern Victoria, Australia. The farm consists of 41 ha of border check irrigated perennial ryegrass-based pastures, with another 15 ha of dryland pasture and cereal crops for grazing. The farm has a milking herd of 156 Holstein Friesian cows, with approximately 60% calving in spring and the remainder in autumn. Cows were milked through three Lely Astronauts robotic milking units, with voluntary cow movement through three grazing areas to facilitate a target milking frequency of three times per day.

In addition to grazed pasture, in the month of November 2017 when this experiment was conducted, the cows were offered 7.6 kg DM/day of concentrate feed in the AMS which had 16% crude protein (CP) and 12.5 MJ ME/kg DM. The estimated daily average pasture intake in the month was 13.5 kg DM/cow.

Pasture and cow entry measurements

Pasture mass and nutritive characteristics were measured during the morning grazing allocation on two consecutive days (29-30 November 2017). On each day pasture mass was measured using a calibrated electronic plate meter every hour from the time that the first cow entered the paddock to the time that the last cow entered (5:20-11:30 am). Every second hour, grab samples of pasture from 20 locations in the paddock were collected for analysis of nutritive characteristics. These samples were collected from the area and plant parts that the herd was grazing at the time of sampling, rather than an average of the pasture available, to give an indication of what the cows were consuming at each point in time. The pasture samples were dried on the oven at 60°C for 72 hours, ground, and analysed by near-infrared spectroscopy for CP and ME at the laboratory of New South Wales Department of Primary Industries, Pine Gully Road, Wagga Wagga.

The time of entry of each cow into the grazing paddock, as well as the total number of animals grazing, was recorded throughout the grazing allocation.

Milking time and milk production

Milking time of each cow was recorded by the automatic milking system and used to determine the daily rank order of cows in November 2017. Cows that were consistently ‘early’ or ‘late’ in the milking order where identified using the average and variance of daily rankings. Daily milk production records (milk yield in kg/day, fat and protein in percentages) for the ‘early and late’ cows were extracted for the month of November and used to determine the milk production differences between these groups. In addition to control for differences in genetic merit and lactation stage, the milk production of an ‘average’ cow in the herd at 60-days in milk was predicted using GrazFeed (Freer et al. 1997) for the ‘early’ and ‘late’ cows using pasture characteristics at the start and end of the grazing allocation and feeding 7.6 kg DM/cow of concentrates.
Results and Discussion

Milking time records demonstrated that there were groups of cows that were consistently ‘early’ and ‘late’ in the milking order, as evidenced by the relatively low variability in their rank order for cows below the 30th percentile of mean rank position and above the 70th percentile (Figure 1). This finding is consistent with Beggs et al. (2017). In this study, average energy corrected milk production of ‘early’ and ‘late’ cows was 36.4 and 29.3 kg/day during November 2017, respectively.

Figure 1. Mean rank percentile position of individual cows versus variance for a herd of 156 cows in November 2017.

On both 29th and 30th November, pasture mass decreased through the grazing cycle as the number of cows in the paddock increased up to a maximum of 90 cows (Figure 2). Pasture nutritive characteristics (CP and ME) also declined through the grazing allocation, but this was more pronounced for CP compared to ME and larger on the 29th November compared to 30th November (Figure 3).

Figure 2. Pasture mass and number of cows in the paddock at 1-hourly intervals during the grazing allocation on the mornings of 29 and 30 November 2017.
Figure 3. Pasture crude protein (CP, %) and metabolizable energy (ME, MJ/kg DM) at 2-hourly intervals during the grazing allocation on the mornings of 29 and 30 November.
‘Early’ cows entered the pasture at an average mass of 3,250 kg DM/ha and consumed pasture with 10.4 MJ ME/kg DM, while ‘late’ cows entered at 1,850 kg DM/ha and consumed pasture with 9.9 MJ ME/kg DM (Figures 2 and 3). GrazFeed modelling of cows in early lactation consuming 7.6 kg DM/day pellets and offered pasture with the average mass and DMD at time of entry of ‘early’ and ‘late’ cows, predicted that ‘early’ cows would produce 2.1 kg/day more milk than ‘late’ cows. This represented 31% of the measured milk production difference between the two groups. Other differences between the groups were that ‘early’ cows tended to have fewer days in lactation and had higher milking frequency which also would have contributed to their higher milk production.

This research highlights the important role that the interactions between pasture characteristics and cow grazing behaviour play in determining milk production from animals within the herd. However, this research was conducted on one farm for a period of one month and further research is required to confirm the patterns of milking order, pasture depletion and milk production across a range of production systems before recommendations for any management changes can be made.

References


A case study: altering month of calving affects economic performance in a temperate pasture-based dairy system.

Short title: Season of calving and profitability

OK Spaans¹, KA Macdonald¹, M Neal¹, MJ Auldist², JAS Lancaster¹, AM Bryant¹, GJ Doole¹, and Roche JR¹,²,³,₄*

¹DairyNZ, Private Bag 3221, Hamilton, New Zealand.
²Agriculture Victoria, 1301 Hazeldean Road, Ellinbank VIC 3821, Australia
³School of Biological Sciences, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand.
⁴Ministry for Primary Industries, PO Box 2526, Wellington 6140, New Zealand.
*Corresponding author. Email: john.roche@mpi.govt.nz

Abstract
Traditionally, it has been assumed that a late winter calving date in temperate dairy grazing systems best matches pasture supply and herd demand, thereby maximising profitability. Our objective was to define the effects of season of calving on financial performance in a grazing system. A stochastic risk analysis of the effect of changing the planned start of calving from winter (July; JUL) to late spring (October; OCT), summer (January; JAN), or autumn (April; APR) on pasture and animal production, and profitability was undertaken. Pasture conservation, body weight, and post-calving body condition score measures were affected by changes in the month of calving ($P < 0.05$), with a tendency ($P < 0.1$) for the JUL herd to have greater milk yield, milk fat, and protein production. Gross farm revenue and operating profit per hectare were modelled under two scenarios; a) no premium for out of season milk, or b) with a premium included for out of season milk. Operating expenses/ha did not differ between herds. However, irrespective of whether or not a ‘winter milk premium’ was applied, operating profit/ha was greater in the JUL herd relative to the APR, OCT, or JAN herds by $300 - $1000/ha.

Introduction
Successful temperate grazing systems produce relatively low cost milk by maximising the utilisation of grazed pasture in the cows’ diet (Dillon et al., 2005; Macdonald et al., 2017; Roche et al., 2017). Since pasture growth rates vary throughout the year, with peak growth during spring (Roche et al., 2009), herds are traditionally managed such that the planned start of calving (PSC) occurs in late-winter. This ensures that the high nutrient demand at peak lactation coincides with seasonal peaks in pasture yield (Roche et al., 2009), and the lowest nutrient demand (i.e., the non-lactating period) coincides with lowest pasture yield in winter (Dillon et al., 1995; McCarthy et al., 2012). However, return on investment for milk processors is negatively affected by the marked peak to trough supply profile that occurs when most of their milk suppliers follow this seasonally-concentrated calving pattern. Therefore, milk purchasers are often prepared to offer a premium for milk produced outside the traditional supply period (Davis and Kirk, 1984; Keane, 2010). The aim of the current case study was to determine the effect of changing the PSC in a compact-calving, pasture-based grazing system, and the relative risks associated with milk price and production inputs, on gross farm revenue and expenses, and operating profit in a system not importing feed from off-farm.

Materials and methods
The experiment was conducted over two lactations at No. 2 Dairy, DairyNZ, Hamilton, New Zealand, all experimental procedures were approved by the Ruakura Animal Ethics Committee, New Zealand. Eighty Holstein-Friesian cows were randomly allocated into four herds of 20 cows, which were randomly assigned to one of four farmlet treatments: PSC 10\textsuperscript{th} January (\textbf{JAN}), 10\textsuperscript{th} April (\textbf{APR}), 10\textsuperscript{th} July (\textbf{JUL}), or 10\textsuperscript{th} October (\textbf{OCT}). Sixty-four paddocks (i.e., defined grazing area 0.405 ha) were randomly allocated to one of the four farmlets (i.e., 6.7 ha/farmlet) and these farmlets remained unchanged throughout the experiment.

Data were analysed for consistency of response to the different calving date treatments over two years (yr) by calculating means for each variable for each farmlet in each yr and analysing these using ANOVA procedures in GENSTAT, with yr and farmlet as fixed effects, and the interaction of farmlet and yr as a random effect (Macdonald \textit{et al.}, 2017). A \( P \) value < 0.05 was considered statistically significant. Milk and pasture production data were averaged across years to provide one value per farmlet. The percentage of cows replaced each year (20\%) was the same across farmlets. Each farmlet was managed individually according to the stage of lactation of the herd; however, each stage was managed similarly across the herds.

Milk payment was calculated individually for each herd, using Fonterra’s guidelines (Chikazhe \textit{et al.}, 2017), which was comprised of a base price ($4.05/kg fat and $8.10/kg protein), a premium for out-of-season supply (16-31\textsuperscript{st} May = $2.85/kg fat and protein; milksolids; MS, 1-15\textsuperscript{th} June = $3.50/kg MS, 16-30\textsuperscript{th} June = $3.50/kg MS, 1-15\textsuperscript{th} July = $2.85/kg MS), a capacity adjustment, and a volume adjustment penalty. The milk price received with the winter premium included was $6.60 for the JAN herd, $6.60 for the APR herd, $5.97 for the JUL herd, and $6.54/kg MS for the OCT herd. The standardised milk price received without the winter premium was $6.16/kg MS. A stochastic model was created using Monte Carlo techniques (Palisade, 2017) to replace single estimates of the variables of interest with a distribution based on historical data and, therefore, assess the risk to profit of the alternative calving date treatments.

\textbf{Results and discussion}

Effects of season of calving on important biophysical attributes of pasture-based dairy farming systems and associated economic performance were examined in the current case study. Very few studies have evaluated the assumption that profit is maximised by establishing the PSC during late winter, which is the norm (Dillon \textit{et al.}, 1995), and none that ensured stocking rate was identical under the different calving date treatments. Furthermore, although biophysical changes associated with changing PSC from winter to autumn have been reported, the profitability of both options has not been considered in a nutritionally-unconfounded comparison; neither has the ‘risk’ to profitability from altering season of calving, with relevant changes in pasture growth, milk price, and input prices, been evaluated.

The effect of change in month of calving on biophysical measures of pasture growth, herd intake and milk production, and bodyweight and body condition score are summarised in Table 1. The JUL herd had the highest pasture growth, and pasture and total dry matter intake reflecting the best match between herd demand and pasture availability.

\textbf{Table 1.} Effect of change in month of onset of calving\textsuperscript{1} (JAN; APR; JUL; OCT) in a seasonal calving system on pasture growth (kg DM/ha), pasture, supplement and total DMI (kg DM/ha), pasture conserved as silage (kg DM/ha), lactation length (d); mean annual milk, milk fat, and protein production (kg/cow); average milk fat, and protein composition (%); body weight (BW; kg) and body condition score (BCS) 1 mo pre-calving and 1 wk post-calving.
Associated effects on farm profitability metrics under two scenarios of a) no premium for out of season milk or b) with a premium included for out of season milk are presented in Table 2. Including an adjustment for winter milk premium increased gross revenue by $409, $428, and $344/ha on average for the JAN, APR, and OCT herds, respectively. However, gross revenue in the JUL herd declined by $213/ha under the adjusted payment system, because of a downward adjustment on milk price for milk produced during peak supply (Table 2; Chikazhe et al., 2017). Nevertheless, despite the lower average milk price, gross revenue remained greatest for the JUL treatment because of the greater milk production/ha ($P < 0.1), compared with the other three calving date treatments. Operating expenses/ha were not greatly affected by calving date treatment, with only small differences in the cost of making silage and requirements for purchased pasture silage. Operating profit/ha was greatest in the JUL calving treatment, irrespective of whether or not a winter milk premium was included.

Table 2. Effect of change in month of onset of calving (JAN, APR, JUL, and OCT) and stochastic input variable, on revenue items, expense items, and output variables gross farm revenue ($/ha), operating expenses ($/ha), and operating profit ($/ha), modelled under two scenarios of a) no premium included; and b) with premium included in the milk payment variable using @Risk software (Palisade, 2017).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Scenario</th>
<th>JAN</th>
<th>APR</th>
<th>JUL</th>
<th>OCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>JAN</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>APR</td>
<td>17,389</td>
<td>17,767</td>
<td>19,327</td>
<td>16,741</td>
<td></td>
</tr>
<tr>
<td>JUL</td>
<td>1,965</td>
<td>1,158</td>
<td>1,247</td>
<td>2,029</td>
<td></td>
</tr>
<tr>
<td>OCT</td>
<td>1,463.1</td>
<td>216.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stocking rate (cows/ha)</td>
<td>0.46</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasture growth (kg DM/ha)</td>
<td>0.28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasture conservation (kg DM/ha)</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasture DMI (kg DM/ha)</td>
<td>0.32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass silage DMI (kg DM/ha)</td>
<td>0.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total intake (kg DM/cow)</td>
<td>0.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lactation length</td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk yield (kg/cow)</td>
<td>0.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat (kg/cow)</td>
<td>0.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat (%)</td>
<td>0.28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (kg/cow)</td>
<td>0.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (%)</td>
<td>0.05</td>
<td></td>
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<tr>
<td>Pre-Calving BW, kg</td>
<td>0.01</td>
<td></td>
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</tr>
<tr>
<td>Post-Calving BW, kg</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Calving BCS (1-10 scale)</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Calving BCS (1-10 scale)</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1JAN = planned calving date of herd 10th January; APR = planned calving date of herd 10th April; JUL = planned calving date 10th July; OCT = planned calving date 10th October.
2SE of the difference.
3Where 1 = emaciated and 10 = obese.
### Revenue

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>±</th>
<th>±</th>
<th>±</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net milk sales/ha</td>
<td>5,718</td>
<td>5,990</td>
<td>6,889</td>
<td>5,578</td>
<td></td>
</tr>
<tr>
<td>Net stock income</td>
<td>N/A</td>
<td>436</td>
<td>408</td>
<td>398</td>
<td>350</td>
</tr>
<tr>
<td>Surplus silage sales</td>
<td>N/A</td>
<td>0</td>
<td>23</td>
<td>136</td>
<td>5</td>
</tr>
</tbody>
</table>

### Expenses

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>±</th>
<th>±</th>
<th>±</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplements purchased</td>
<td>6,153</td>
<td>6,421</td>
<td>7,424</td>
<td>5,932</td>
<td></td>
</tr>
<tr>
<td>Silage conservation</td>
<td>N/A</td>
<td>233</td>
<td>174</td>
<td>245</td>
<td>297</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N/A</td>
<td>244</td>
<td>244</td>
<td>244</td>
<td>244</td>
</tr>
</tbody>
</table>

### Gross farm revenue

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>±</th>
<th>±</th>
<th>±</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6,562</td>
<td>6,849</td>
<td>7,211</td>
<td>6,276</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,479</td>
<td>1,564</td>
<td>1,804</td>
<td>1,459</td>
<td></td>
</tr>
</tbody>
</table>

### Operating Expenses

|                        | N/A | 4,304 | 4,099 | 4,142 | 4,202 |

### Operating Profit

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>±</th>
<th>±</th>
<th>±</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,850</td>
<td>2,322</td>
<td>3,282</td>
<td>1,730</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2,258</td>
<td>2,749</td>
<td>3,069</td>
<td>2,079</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,501</td>
<td>1,556</td>
<td>1,769</td>
<td>1,458</td>
<td></td>
</tr>
</tbody>
</table>

1 JAN = planned calving date of herd 10th January; APR = planned calving date of herd 10th April; JUL = planned calving date 10th July; OCT = planned calving date 10th October.

2 Fitted distribution means: Meat price = $3.09/kg; urea price = $711/t; silage purchase = $287/t DM; silage sale = $187/t DM; make silage = $137/t DM

3 Scenario a) no premium included in milk payment variable ($6.16/kg MS for JAN, APR, JUL, and OCT herds); scenario b) premium for milk supplied during 16 May - 15 July included in milk payment variable ($6.60, $6.60, $5.97, and $6.54/kg MS for JAN, APR, JUL, and OCT herds, respectively).

4 Amount of silage purchased, sold and made based on modelled amount of pasture growth due to annual growth variation during trial.

### Conclusions

Designing a pasture-based system, such that PSC occurred during winter, resulted in a greater proportion of grazed fresh pasture in the diet of the lactating cow, and an increase in milk production relative to the other calving dates. When variability in pasture growth, input prices, and milk prices was considered, the JUL calving treatment was consistently the most profitable.
Acknowledgements

The authors acknowledge all the help afforded them by No 2. Dairy staff, A. Duker and L. Bowler, and the statistical expertise of B. Dow. This work was funded by New Zealand dairy farmers through DairyNZ Inc., Hamilton, New Zealand.

References


Improved milk production from Palm Kernel treated with a Trichoderma extract

K.B. Greaney¹ and P.W. Harrison²

¹AB Vista, 666 Great South Rd, Ellerslie, Auckland, NZ
²AgriFeeds, 18 Rostrevor St, Hamilton, NZ

Abstract

The objective of this study was to quantify productive responses to the treatment of Palm Kernel Expeller (PKE) with an exogenous *Trichoderma* extract (VistaPre-T (VPT); AB Vista) under commercial New Zealand dairy conditions.

In the first study, 205 pregnant cows at approximately 170 days in milk (DIM) were randomly allocated to either control (138) or treatment (67) groups. PKE was offered at 3.4 kg/cow/d via PKE troughs following the morning milking only, whilst cows grazed a turnip crop. Cows receiving VPT treated PKE (0.75 ml/kg DM) produced more milk solids (+106 g MS/cow/d, \( P = 0.038 \)) than cows fed the untreated PKE.

In the second study, non-pregnant cows at two different stages of lactation (100 cows @ 300 DIM and 163 cows @ 75 DIM), were randomly allocated to control or treatment (+VPT) groups. All cows were offered 3.5 kg/cow/d of a commercial feed blend during milking (50% PKE, 30% canola, 10% sugar, 10% soya hull pellets). VPT was applied to the treatment blend at 0.75 ml/kg DM. The milk solids response to VPT was significant in early lactation (75 DIM) group (+117g MS/cow/d, \( P = 0.045 \)), whereas in the later lactation group (300 DIM), there was a tendency to increased milk solids production (+124 g MS/cow/d, \( P = 0.067 \)).

These two studies indicate that VPT treatment of PKE can improve milk solids yield by over 100g MS/cow/d.

Introduction

Palm Kernel Expeller (PKE) is fed extensively to New Zealand dairy cows to enhance lactation yields. With approximately 2 million MT of PKE imported into New Zealand annually, this represents a significant proportion of the supplementary feed offered to the national dairy herd. The nutritive value of PKE is typically 88-95% dry matter, 10.5-11.5 MJ/kg DM metabolizable energy and 14-16% crude protein (Dias, 2010), which is a suitable nutrient profile for a supplementary dairy feed forming a proportion of a ration. The current work quantifies the production responses to feeding PKE treated with a crude extract of *Trichoderma*, with the hypothesis that supplementation of PKE with this extract will increase milk yields, confirming international work (Walker and Povey, 2016).

Materials and methods

Two experiments were conducted in a commercial dairy herd to quantify the milk production responses to feeding palm kernel treated with a *Trichoderma* extract.

In experiment 1, 205 mixed aged and parity pregnant cows at approximately 170 days in milk (DIM) were randomly allocated to control and treatment groups, with approximately 2/3 of the cows
allocated to the control group (138 cows) and 1/3 to the treatment group (67 cows), as only three PKE troughs were available. The cows were auto-drafted during the morning milking into the two separate herds, which then grazed the same paddock of turnips, with the daily allocation divided 2/3 and 1/3, for the control and treatment herds, respectively. The PKE was fed via the PKE troughs placed in the divided turnip paddock during the day, for a total of 45 days. Following the afternoon milking, both herds were combined and grazed fresh pasture.

The crude extract of *Trichoderma* (VistaPre-T, {VPT}, AB Vista, UK) was applied at a rate of 0.75 ml/kg PKE DM. Approximately 500L of water was first added to all PKE troughs. VPT was added to the treatment trough only, then thoroughly mixed to ensure that the VPT was fully dispersed in the water prior to the PKE being added, and again thoroughly mixed, thereby ensuring that the VPT contacted all of the treatment PKE. PKE troughs were prepared in the evening, approximately 15 hours prior to feeding. Cows were offered 3.4 kg/d of PKExtra 20 (AgriFeeds, Hamilton, New Zealand), which contained approximately 20% molasses added to the PKE.

In experiment two, using only non-pregnant mixed aged and parity cows, 163 cows at approximately 75 DIM (early lactation) and 100 cows at approximately 300 DIM (late lactation), were randomly allocated to control and treatment groups, within DIM. Cows were treated identically, including feeding 3.5 kg/cow/d of a blend (50% PKE, 30% canola meal, 10% sugar and 10% soy hull pellets), fed in-shed during each milking, with the exception that the treatment group blend was supplemented with VPT at a rate of 0.75ml/kg PKE DM, diluted 1:10 in water. The VPT was added at a commercial blend plant up to 4 weeks prior to feeding. All cows grazed fresh pasture between milkings as a single herd, for 14 weeks.

Milk yield parameters were recorded for each milking with in-shed, individual cow Afimilk data recording.

An analysis of variance between the treatment means was performed with SAS using Proc ANOVA (SAS, 2011).

**Results**

In experiment one, VPT supplementation of the PKE fed via the PKE troughs resulted in significantly higher milk solids (+106 g MS/cow/d, \( P = 0.038 \)) than cows fed the untreated PKE (Table I). There were no significant differences in fat or protein percentages as a result of VPT treatment. Body weight changes were similar between the two groups, with both groups losing weight over the experimental period.

In experiment two, the early (75 DIM) lactation cows produced more milk solids as a result of VPT supplementation (+117g MS/cow/d, \( P = 0.045 \), Table II). In the later lactation group (300 DIM), there was only a numeric tendency towards increased milk solids production (+124 g MS/cow/d, \( P = 0.067 \), Table III). Milk volume was significantly increased over both stages in lactation (+1.54 l/d, \( P = 0.039 \) for the early lactation group, and +1.61 l/d, \( P = 0.040 \) for the late lactation group. There were no significant changes in body weight in experiment 2, with both groups of cows gaining weight.

**Discussion**

Both experiments showed improved milk solids production following the addition of the crude extract of *Trichoderma* to PKE, confirming the hypothesis of elevated milk production. These responses were consistently recorded across the three stages of lactation evaluated, suggesting that elevated milk
production responses to the supplementation of PKE with *Trichoderma* can be expected throughout lactation.

Despite both groups of cows in experiment one losing weight during the experimental period, the supplementation of VPT generated a higher milk solid yield (+106 g/d, *P* = 0.038), which confirmed previous international work (Walker and Povey, 2016). This improvement in milk solid production was attributed to a significant increase in fat yield and a trend towards increased protein yield (Table I). There was no significant difference in milk volume as a result of VPT treatment in experiment one.

Experiment two recorded significantly elevated milk volume responses for both the early and late lactation groups. This was accompanied by significantly higher milk solid yields for the VPT supplemented group in early lactation; however, this difference was only a trend for the later lactation group. There were no significant treatment differences for fat or protein percentages, confirming that the recorded differences in milk solids were largely due to the improvement in milk volumes. These improvements in productive indices confirm earlier work (Walker and Povey, 2016).

**Conclusion**

These two experiments have demonstrated the positive effect of VPT on milk production indices in a commercial herd fed PKE. The responses in milk solid yield have been consistent across the three stages of lactation investigated and were similar whether the VPT was delivered directly on-farm into the PKE troughs, or applied off-farm into commercial blends. These data confirm that VPT addition to PKE can result in elevated milk solids production.

**References**


Table I – mid-lactation (170 DIM) milk production and body weight data following the feeding of PKE supplemented with a *Trichoderma* extract, as fed via PKE troughs (Experiment 1)

<table>
<thead>
<tr>
<th></th>
<th>Control Start</th>
<th>Change</th>
<th>VPT Start</th>
<th>Change</th>
<th>Trt effect (%)</th>
<th>SED</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk solids (kg/d)</td>
<td>1.98</td>
<td>-0.28</td>
<td>1.98</td>
<td>-0.18</td>
<td>+0.11 (5.4)</td>
<td>0.0048</td>
<td>0.038</td>
</tr>
<tr>
<td>Volume (l/d)</td>
<td>23.94</td>
<td>-3.28</td>
<td>23.82</td>
<td>-2.42</td>
<td>+0.87 (3.6)</td>
<td>0.2904</td>
<td>0.127</td>
</tr>
<tr>
<td>Fat yield (kg/d)</td>
<td>1.09</td>
<td>-0.17</td>
<td>1.10</td>
<td>-0.10</td>
<td>+0.66 (6.0)</td>
<td>0.0037</td>
<td>0.033</td>
</tr>
<tr>
<td>Fat %</td>
<td>4.57</td>
<td>-0.06</td>
<td>4.68</td>
<td>0.06</td>
<td>+0.12 (2.6)</td>
<td>0.0010</td>
<td>0.106</td>
</tr>
<tr>
<td>Protein yield (kg/d)</td>
<td>0.89</td>
<td>-0.12</td>
<td>0.87</td>
<td>-0.08</td>
<td>+0.04 (4.8)</td>
<td>0.0032</td>
<td>0.056</td>
</tr>
<tr>
<td>Protein %</td>
<td>3.72</td>
<td>0.02</td>
<td>3.67</td>
<td>0.06</td>
<td>+0.04 (0.9)</td>
<td>0.0006</td>
<td>0.133</td>
</tr>
<tr>
<td>Body wt (kg)</td>
<td>528.7</td>
<td>-8.2</td>
<td>533.0</td>
<td>-7.6</td>
<td>+0.59 (0.1)</td>
<td>0.4988</td>
<td>0.699</td>
</tr>
</tbody>
</table>

Table II – early lactation (75 DIM) milk production and body weight data following the feeding of PKE supplemented with a *Trichoderma* extract, as fed via a commercial blend (Experiment 2)

<table>
<thead>
<tr>
<th></th>
<th>Control Start</th>
<th>Change</th>
<th>VPT Start</th>
<th>Change</th>
<th>Trt effect (%)</th>
<th>SED</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk solids (kg/d)</td>
<td>2.19</td>
<td>-0.05</td>
<td>2.04</td>
<td>+0.07</td>
<td>+0.12 (5.7)</td>
<td>0.0012</td>
<td>0.045</td>
</tr>
<tr>
<td>Volume (l/d)</td>
<td>27.50</td>
<td>-0.74</td>
<td>25.40</td>
<td>+0.80</td>
<td>+1.54 (6.1)</td>
<td>0.4339</td>
<td>0.039</td>
</tr>
<tr>
<td>Fat yield (kg/d)</td>
<td>1.20</td>
<td>-0.03</td>
<td>1.11</td>
<td>+0.04</td>
<td>0.06 (5.7)</td>
<td>0.0009</td>
<td>0.066</td>
</tr>
<tr>
<td>Fat %</td>
<td>4.40</td>
<td>0</td>
<td>4.39</td>
<td>0</td>
<td>0 (0.09)</td>
<td>0.0013</td>
<td>0.958</td>
</tr>
<tr>
<td>Protein yield (kg/d)</td>
<td>0.99</td>
<td>-0.02</td>
<td>0.93</td>
<td>+0.04</td>
<td>0.05 (5.7)</td>
<td>0.0008</td>
<td>0.047</td>
</tr>
<tr>
<td>Protein %</td>
<td>3.65</td>
<td>+0.02</td>
<td>3.68</td>
<td>+0.01</td>
<td>-0.01 (0.03)</td>
<td>0.0017</td>
<td>0.597</td>
</tr>
<tr>
<td>Body wt (kg)</td>
<td>498.4</td>
<td>-6.8</td>
<td>491.1</td>
<td>+2.8</td>
<td>+2.4 (0.5)</td>
<td>0.6499</td>
<td>0.146</td>
</tr>
</tbody>
</table>

Table III – late lactation (300 DIM) milk production and body weight data following the feeding of PKE supplemented with a *Trichoderma* extract, as fed via a commercial blend (Experiment 3)

<table>
<thead>
<tr>
<th></th>
<th>Control Start</th>
<th>Change</th>
<th>VPT Start</th>
<th>Change</th>
<th>Trt effect (%)</th>
<th>SED</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk solids (kg/d)</td>
<td>1.69</td>
<td>0</td>
<td>1.49</td>
<td>+0.10</td>
<td>+0.12 (8.3)</td>
<td>0.0011</td>
<td>0.067</td>
</tr>
<tr>
<td>Volume (l/d)</td>
<td>19.48</td>
<td>-0.13</td>
<td>17.12</td>
<td>+1.52</td>
<td>+1.61 (9.4)</td>
<td>0.3884</td>
<td>0.040</td>
</tr>
<tr>
<td>Fat yield (kg/d)</td>
<td>0.95</td>
<td>+0.01</td>
<td>0.84</td>
<td>+0.06</td>
<td>+0.05 (6.4)</td>
<td>0.0009</td>
<td>0.178</td>
</tr>
<tr>
<td>Fat %</td>
<td>4.92</td>
<td>+0.06</td>
<td>4.96</td>
<td>-0.06</td>
<td>-0.12 (1.8)</td>
<td>0.0013</td>
<td>0.274</td>
</tr>
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<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td></td>
</tr>
<tr>
<td>Protein yield</td>
<td>0.74</td>
<td>0</td>
<td>0.64</td>
<td>+0.07</td>
<td>+0.07 (1.4)</td>
<td>0.0008</td>
<td></td>
</tr>
<tr>
<td>(kg/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td>Protein %</td>
<td>3.80</td>
<td>+0.03</td>
<td>3.78</td>
<td>+0.06</td>
<td>+0.03 (0.9)</td>
<td>0.0008</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.253</td>
<td></td>
</tr>
<tr>
<td>Body wt (kg)</td>
<td>533.0</td>
<td>+4.6</td>
<td>537.3</td>
<td>+5.8</td>
<td>+1.1 (0.2)</td>
<td>0.668</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>0.472</td>
<td></td>
</tr>
</tbody>
</table>
Correcting for time dependant drift in ruminal pH sensors

S. R. O. WILLIAMS *, W. J. WALES AND P. J. MOATE
Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia

* Corresponding author. E-mail: richard.williams@ecodev.vic.gov.au

Abstract

Measurements made by electronic sensors may drift over time. We propose the following time-dependent correction equation (1) which allows for an offset at pre-use calibration and drift as detected at post-use validation.

\[
\text{Actual value} = \left( a_0 + b_0 X \right) \times \left( 1 - \frac{\delta}{\Delta} \right) + \left( a_\Delta + b_\Delta X \right) \times \left( \frac{\delta}{\Delta} \right)
\]

Where \( a_0 \) and \( b_0 \) are calibration constants at time 0, while \( a_\Delta \) and \( b_\Delta \) are calibration constants at validation time \( \Delta \) (hours after time 0), \( X \) is the variable of interest (for example, ruminal pH) and \( \delta \) is the elapsed duration (h) between time 0 and the time of measurement. The equation was tested on pH data from 328 cow-days. The pH sensors were calibrated in standard solutions (pH 4 and 7) before and after use. Linear calibration equations were created for time 0 and time \( \Delta \) then Equation 1 was used to correct all recorded ruminal pH data. The average (± standard deviation) drift across all sensors at all deployments was -0.06 ± 1.58%/day. A similar approach has been used to successfully correct drift in temperature loggers.

Our equation corrects for errors in sensor data due to initial offset and linear drift over time. It also allows for sensors to be calibrated and validated at convenient times rather than immediately pre and post deployment.

Keywords

calibration; rumen; sensors

Introduction

Electronic devices to measure ruminal pH have been described by numerous researchers (e.g.: Coleman et al. 2010; Penner et al. 2006) but their measurements can drift with time. Several strategies have been used to manage this drift including frequent calibration (Bevans et al. 2005), limiting the duration of observations (Mullins et al. 2012), and mathematically adjusting the recorded data (Kaur et al. 2010; Palmonari et al. 2010). Published drift correction procedures include adjusting for linear change in pH (Kaur et al. 2010) and linearly apportioning measured drift after physical recovery of the sensor (Palmonari et al. 2010). The drift correction of Palmonari et al. (2010)
uses measurement number as the increment and does not include an allowance for an initial discrepancy between the pH as recorded by the sensor and the true pH.

We propose the following novel, time dependent equation (1).

\[
\text{Actual value} = \left( (a_0 + b_0 X) \times \left( 1 - \delta \frac{\Delta}{\Delta} \right) \right) + \left( (a_\Delta + b_\Delta X) \times \left( \delta \frac{\Delta}{\Delta} \right) \right)
\]  

(1)

Where \(a_0\) and \(b_0\) are calibration constants at time 0, while \(a_\Delta\) and \(b_\Delta\) are calibration constants at validation time \(\Delta\) (hours after time 0), \(X\) is the variable of interest (for example, pH) and \(\delta\) is the elapsed duration (h) between time 0 and the time of measurement. This equation allows for the possibility of an offset to account for any discrepancy between pH as measured by the intra-ruminal sensor and the pH standard in the period immediately before the intra-ruminal sensor is placed in the rumen. Eqn. (1) also allows for a time dependent, linear drift correction procedure to cover the period from pre-use calibration to post-use validation.

Although it has been reported that pH sensors may drift (Kaur et al. 2019; Palmonari et al. 2010) the extent of this drift has not been well documented. The aim of this research was to measure and document the extent of drift in intra-ruminal pH sensors, present a novel equation that can be used to correct data with respect to this drift, and demonstrate the use of this drift correction process with actual data.

**Materials and methods**

Ruminal pH data from 27 intra-ruminal boluses (KB5; Kahne Limited, Auckland, New Zealand) were collated from three experiments with 10 unique diets (Table 1). The boluses were calibrated before use in solutions of pH 4 and 7. The boluses were then placed in the rumen of rumen fistulated cows where they remained for between 3 and 7 days before being retrieved. Post-use, the boluses were rinsed in cold, clean tap water and were then validated in solutions of pH 4 and 7 by simply recording the measured pH. Linear calibration equations at time 0 and \(\Delta\) were developed based on the calibration and validation results. The calibration slopes (\(b_0\)) at time \(\Delta\) were divided by \(\Delta\) and multiplied by 100 to give the percentage change in calibration slope per day for each bolus at each deployment.

**Table 1: Summary of experiments where pH data were collected.**

1 7 days on 3 different occasions.
The boluses were deployed in 31 different, ruminally fistulated, Holstein-Friesian dairy cows and data was collected every five minutes. The 91,600 time-point records were processed with no allowance for sensor drift (RAW) and Eqn. (1) was used to produce drift-corrected data (COR). Processing was done using Excel 2016 (Microsoft Corporation, Redmond, Washington, Unites States) and resulted in 328 cow-days of summary records for each of RAW and COR. The difference between each RAW and COR record pair was calculated for the mean pH, minimum pH, maximum pH, duration pH less than 6 (h), and the area less than pH 6 (pH.h).

### Results

Plots of RAW ruminal pH over time showed that drift was linear (Fig. 1, example only).

**Fig. 1:** Example of drift correction of ruminal pH data collected using intra-ruminal boluses.
The daily drift percentage varied between boluses and between deployments (Fig. 2, not all boluses shown). For some sensors, the drift was negative (recorded pH less than actual), while for some the drift was positive, (recorded pH greater than actual). The average (± standard deviation) drift across all sensors at all deployments was \(-0.06 \pm 1.58\%/\text{day}\). Drift ranged from \(-7.23\%/\text{day}\) to \(+9.72\%/\text{day}\).

**Fig. 2:** Example drift rates of intra-ruminal boluses used to record ruminal pH.

On average, RAW pH data overestimated the daily mean pH, minimum pH and maximum pH, but underestimated the duration pH was less than 6 and the area less than pH 6. However, for individual boluses on separate deployments the differences ranged from large underestimations to large overestimations (Table 2).

**Table 2:** Differences between daily pH statistics when calculated using raw measurements or those corrected for sensor drift. (328 records)

<table>
<thead>
<tr>
<th>pH statistic</th>
<th>Maximum underestimate</th>
<th>Maximum overestimate</th>
<th>Mean(^1)</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.53</td>
<td>0.83</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>Min</td>
<td>0.73</td>
<td>0.79</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td>Max</td>
<td>0.56</td>
<td>0.92</td>
<td>0.09</td>
<td>0.06</td>
</tr>
</tbody>
</table>

\(^1\) positive values are an overestimate, negative values are an underestimate
### Discussion

Our equation (1) corrects for errors in sensor data due to initial offset and linear drift over time. It also allows for sensors to be calibrated and validated at convenient times rather than immediately prior to and immediately post deployment. This is because the adjustment is time based and not reliant on reading number, meaning the scheduling of calibration and validation is accounted for by the equation design rather than needing to be done as the readings immediately pre and post use. As well as reducing the need to limit the duration of deployment of boluses within the rumen (Penner et al. 2006; Mullins et al. 2012), our equation also eliminates the need to calibrate sensors frequently (Bevans et al. 2005; Dohme et al. 2008; Sullivan et al. 2012), and it allows data from sensors identified as having drifted to be used instead of being discarded.

Daily drift was generally small, with some exceptions, but over time the drift can become significant. Thus, if a bolus were to be placed within a rumen for only a day or two, as recommended by Mullins et al. (2012), then drift correction may not be necessary. However, substantial drift may occur in longer deployments, and correction would be required. The marked difference in drift between sensors, and within sensors over deployments, indicates that drift needs to be measured and considered for each individual bolus at every deployment.

Drift in the pH sensors was linear as is shown in Figure 1 where the minimum pH increased from day to day in the RAW data but remained steady in the COR data. This agrees with the observations of other researchers (Kaur et al. 2012; Lohölter et al. 2013; Palmonari et al. 2010).

In practice, our equation can be used as described in the methods, namely; calibrate the sensors and record this time as time 0, deploy the sensors, recover the sensors, validate the sensors and record this time as time Δ. Coefficients are calculated for linear regressions between measured and actual values at times 0 and Δ, then actual values are calculated for every reading using the elapsed duration since calibration (δ).

This research focused on drift in pH data, but we have also successfully used our equation to correct for drift in temperature sensors, which cannot be adjusted to remove the initial offset (KBS; Kahne Limited, Auckland, New Zealand).

### Conclusion

Our equation corrects for errors in sensor data due to initial offset and linear drift over time. Daily drift was generally small, with some exceptions, but over time the drift can become significant. We have focussed on correction of drift in pH data, but we have also successfully used our equation to correct for drift in temperature sensors.

### Conflicts of interest

The authors declare no conflicts of interest.
Acknowledgements

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References


Milk yield has an impact on success of milking events in automatic milking systems

F. M. Masia\textsuperscript{13}, N. A. Lyons\textsuperscript{2}, M. Piccardi\textsuperscript{13}, M. Balzarini\textsuperscript{13}, R. C. Hovey\textsuperscript{4} and S. C. Garcia\textsuperscript{5}

\textsuperscript{1} Facultad de Ciencias Agropecuarias de la Universidad Nacional de Córdoba. Argentina.
\textsuperscript{2} NSW Department of Primary Industries. Australia.
\textsuperscript{3} CONICET. Argentina.
\textsuperscript{4} Department of Animal Science, University of California, Davis, California USA.
\textsuperscript{5} Dairy Science Group, The University Of Sydney. Australia.

Abstract

Automatic milking systems (AMS) provide the benefit of unassisted milking events, although a proportion might also be deemed incomplete. Minimising their occurrence is key to overall system performance. A database containing records for 773,483 individual milking events from four AMS farms was used to describe the risk of an incomplete milking event. Each record contained information about farm, cow, lactation, days in milk (DIM), milking interval (MI), milk yield (MY, in kg/milking) and if the milking event was complete or not. An incomplete gamma function with a random cow effect on the intercept was used to model variability amongst cows within their lactation profile, with adjustment for lactation number (1, 2 and 3 or more) and calving period (warm or cool). The best linear unbiased (BLUP) prediction of cow effect was used to categorise lactations into percentile 33 (P33) and 66 (P66), as either high, medium or low MY level respectively. A proportional hazards model was fitted to describe the risk of a complete milking event happening as a function of MY and calving period. First lactation cows with high MY level were 2.05 times more likely (\(P<0.0001\)) to have a complete milking event than those with low MY level. The likelihood was only 1.36 (\(P<0.0001\)) for cows with three or more lactations. Furthermore, lactations that had commenced in the cool period were more likely to have shorter MI than those that commenced in the warm period. Know the milking interval in which complete milking happens for different productive groups would improve the performance of the robot.

Introduction

Automatic milking systems (AMS) are based on voluntary trafficking of cows, which provides the possibility for the cows to set their own milking schedules. Therefore, visitation pattern to the robot varies throughout the lactation (Lyons et al., 2013). This generates variation in milking intervals (MI, defined as the time elapsed between two consecutive milkings, in hours) within and between cows throughout the lactation. This is different to conventional milking systems where MI remains relatively constant both within and between cows. Therefore, cows store different amounts of milk depending on MI. Furthermore, fluctuation in MI have shown to be an attribute of the individual cow (Løvendahl and Chagunda, 2011).

In AMS a robotic arm locates and attaches a cup onto each individual teat. Success of this task depends on several factors, including localisation and insertion of the teats, which in turn is related to the amount of milk in the udder. A complete milking event is defined as that in which the amount of milk harvested is close to the expected yield (around 75 to 80\% of expected yield). On the contrary, an incomplete milking event is defined as any milking event where that threshold is not achieved. Unsuccessful attachment of the cups to one or more teats, or premature cup removal, are some of the causes of incomplete milkings (Lyons et al., 2014). Previous studies have highlighted the
negative impact of an incomplete milking on milk production. This effect increases with the degree and frequency of incomplete milking and varies between cows (Wheelock et al., 1965; Peaker et al., 1996; Stelwagen et al., 1997, Albaaj et al., 2018).

The aim of this study was to quantify the risk of a complete milking in relation to milk yield level (MY) and calving period (CP, defined as warm or cool), with the idea of exploring whether there is a MY at which incomplete milkings are minimised.

Materials and Methods

A database containing 773,483 records of milking events for one year (July 2016 – June 2017) from two AMS farms in Australia and one farm from New Zealand and Chile was used. Each record contained farm, cow, lactation, DIM, MI and MY (as the total amount of milk harvested in one milking event, in kg/milking). Daily MY was calculated as the sum of MY within a 24-h period. An incomplete gamma function (Wood, 1967) with a random intercept (adding a random component distributed normally with zero mean and variance to parameter a of the function) was adjusted for each lactation. Daily yields were expected to be auto-correlated. The adjustments were made using PROC NLMIXED in SAS. Predicted curves of average daily MY according to lactation (1, 2 and 3 or more), and CP were obtained. Animals that calved between September and February were considered as warm CP; those calving between March and August were considered as cool CP. We used BLUP to categorise each lactation in three levels, as high, medium or low, in agreement with the value of the P33 and P66 of yield distribution. Finally, a proportional hazards model was used to determine the risk of a milking event being complete in relation to MY level and CP for 1st, 2nd and 3rd or more lactation.

Results and Discussion

First lactation cows with high MY level (22.81 ± 0.03 kg, as mean ± SEM) were 2.05 (95% CI 2.03 – 2.09) times more likely to have a complete milking event during the observation period than those with low MY level (10.42 ± 0.03 kg, as mean ± SEM). This likelihood reduced to 1.36 (P<0.0001) for cows with three or more lactations. Similar results were reported in a study conducted in a pasture-based AMS, in which probability of success at second attempt (after an initial incomplete milking), was about 7.5 times higher in cows with higher production (Kolbach et al., 2012).

Additionally, Albaaj et al. (2018) found that the total distance between the 4 teat ends increased as the degree of milk removal in the udder decreased. Given that one of the factors that affects the successful location of the teat by the robot is the insertion of the teat, degree of udder fill might be a key factor behind complete milkings.

Long MI, caused for example by incomplete milkings, result in a remnant of milk in the udder, increasing the possibility that bacteria causing mastitis colonise the quarters causing a spike in the incidence of this health event (Hovinen 2011).

First lactation cows had a median MI for complete milkings of 11.55 h for those with high MY and 13.71 h for those with low MY level. For cows with three or more lactations the median MI was 10.9 h for cows with high MY level and 12.56 h for cows with low MY level. Managing milking intervals to achieve complete milkings, without negative effects on production and udder health, could optimise AMS utilisation. This is important in order to maximise the potential achievable throughput (cow milkings/day) without detrimental effects on queue lengths and time off pasture (Davis et al., 2005). Moreover, regardless of the lactation number, cows that calved in a cool period
were more related to having shorter MI for complete milkings, than those that calved in the warm period ($P<0.0001$).

**Conclusion**

Our data indicates there is a positive relationship between production level and complete milkings events for cows in pasture-based AMS. This means that if milk production decreases, it is less likely for the robot to successfully attach the teat cups which causes an increase in the percentage of incomplete milkings. To our knowledge this is the first study to quantify this effect, a necessary first step in solving or reducing the problem. Future research will be necessary to determine in the cows with incomplete milking potential health problems, such as mastitis. Additionally, time in which complete milkings are achieved for each productive group would allow the herds to be scheduled to maximise the number of milkings per day per robot.

**References**


Managing Palm Kernel Expeller to Meet the Fat Evaluation Index Grading System on New Zealand Dairy Farms.

Taisekwa Chikazhe¹, Chris Glassey¹, Alvaro Romera¹, Jane Kay¹ and Rachael Davidson¹

¹DairyNZ, Private Bag 3221, Hamilton 3240, New Zealand
taisekwa.chikazhe@dairynz.co.nz

Abstract

Palm Kernel Expeller (PKE) is a popular supplementary feed option for dairy farmers due to its low price and ease of use relative to other supplementary feeds. However, high levels of PKE fed to lactating cows alter milk fat composition and product specifications. Fonterra has introduced a Fat Evaluation Index (FEI) grading system designed to restrict PKE feeding. Milk price penalties apply if suppliers exceed FEI thresholds. To quantify the economic and environmental impacts of different options for complying with FEI thresholds, six case-study farms representing high, medium, and low PKE use were modelled in Farmax and OVERSEER©. PKE was either removed altogether, or fed to remain below the FEI threshold, in conjunction with changes to types of supplements used, herd size, or class of stock to which PKE was fed. Replacing PKE completely with alternative purchased supplementary feed to maintain herd size reduced operating profit by $99-$398/ha. Removing PKE and reducing herd size to maintain a similar comparative stocking rate (CSR) resulted in $67-$198/ha reduction in operating profit. Adjusting PKE feeding levels while maintaining a similar CSR resulted in $0-$76/ha reduction in operating profit. Substantial reductions in nitrogen leaching and greenhouse gas emissions were only predicted when both PKE fed and herd size were reduced.

Key words

Palm Kernel Expeller, Farm systems modelling, Operating profit.

Introduction

The amount of Palm Kernel Expeller (PKE) imported annually to New Zealand has increased from 15 tonnes in the early 1990’s to almost 2.3 million tonnes in 2017 (MPI, 2017). Feeding PKE has grown in popularity due to its availability, relatively low price, and ease of incorporation into a pasture based system. Use of PKE ranges from strategically maintaining high stocking rates to tactical use during periods of feed deficit. Feeding PKE to pasture fed cows is associated with increased fat content in milk (DairyNZ, 2017; van Wyngaard & Meeske, 2017). It also alters milk fatty acid composition with an increase in concentration of short and medium chain fatty acids (Dias, 2010). It is primarily this change in milk fat composition that impact the processing of fat-based dairy products. Research data indicate a linear relationship between the amount of PKE fed to lactating cows and the concentration of short chain fatty acids (Dias, 2010). However, feeding PKE to non-lactating cows does not affect milk fat composition in the following lactation (DairyNZ, 2017). Fat Evaluation Index (FEI) is an index developed by Fonterra to indicate the suitability of milk fat acid composition for processing. Fonterra FEI grading system is designed to control PKE induced milk fat
acid composition by penalising farmers who exceed thresholds. The main objective of this study was to quantify the economic and environmental impacts of different options for complying with FEI thresholds.

**Methods**

Actual farm physical and financial data for 2014/15 were used to model 6 case study farms across the North Island representing high, medium, and low PKE users. Climate, milk price($6/KgMs) and cost structures in 2014-15 were close to average for the NZ dairy industry. Farmers feeding more than 1 tonne of PKE per cow per year were classified as high users, those feeding between 0.5 and 0.7 tonnes as medium users and those feeding less than 0.25 tonne as low users. FARMAX (Bryant et al., 2010) model was used to simulate the economic impacts of a range of farm system options while OVERSEER® version 6.3 was used to determine the environmental outcomes. It was assumed to comply with FEI grading thresholds, PKE fed to lactating cows should be limited to not more than 15% of daily diet (DairyNZ 2017).

The options modelled were:

1. Removing PKE from the system and:
   a) replacing on a dry matter basis with feeds such as maize silage, or soybean hulls; or
   b) reducing herd size to maintain a similar comparative stocking rate (CSR; kg liveweight per tonne dry matter feed offered).

2. Reduce PKE feeding to 15% of the diet then:
   a) purchasing an alternative supplement to meet the feed shortfall; or
   b) reducing herd size to match feed demand with supply, to maintain the same CSR; or
   c) swapping the remaining PKE with supplements normally fed to non-lactating cows.

The assumed average long-term cost/kgDM of pasture, PKE, purchased maize silage and purchased soybean hulls are presented in Table 1.

**Table 1**: Assumed average long-term cost$/kgDM of pasture, PKE, purchased maize silage, and purchased soybean hulls.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Cost$/kgDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture</td>
<td>0.13</td>
</tr>
<tr>
<td>PKE</td>
<td>0.28</td>
</tr>
<tr>
<td>Maize silage</td>
<td>0.36</td>
</tr>
<tr>
<td>Soybean hulls</td>
<td>0.42</td>
</tr>
</tbody>
</table>

**Results and discussion**
Removing PKE from the system and replacing it with alternative purchased supplementary feeds was the least profitable option investigated (Table 2) because it led to a higher average feed cost (Table 1). Removing PKE and then reducing herd size led to greater environmental benefits and a smaller reduction in predicted operating profit because less total supplementary feed was required. Operating profit was not reduced when PKE fed to lactating was reduced to 15% of the diet and the remaining PKE swapped for supplements usually fed to non-lactating cows. This is a potential low impact option but is not viable if low quality feed such as hay or straw is swapped for PKE in the milking cow diet. Alternatively, when PKE was reduced to 15% of the diet and herd size reduced, there was minimal impact on predicted operating profit (Table 2). In systems where feed management is not optimal, reducing PKE usage and optimising pasture utilisation will increase profitability. Environmental benefits induced by meeting FEI standards are more likely when both stocking rate and PKE fed is reduced, a reflection of less feed inputs coming onto the farm.

Acknowledgements
This work was funded by New Zealand dairy farmers through DairyNZ.

References


Table 2: Predicted implications for profit and environmental emissions of different Palm Kernel Expeller (PKE) feeding strategies for meeting milk grading compliance thresholds when applied to farms currently using high, medium, or low amounts of the feed. * PKE replaced with purchased maize silage, ^ PKE replaced with Soybean hulls.
<table>
<thead>
<tr>
<th>Strategy 1, remove PKE from the system</th>
<th>Strategy 2, feed PKE to compliance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove PKE and replace with other purchased feeds (1a)</td>
<td>Reduce PKE feeding to 15% then replace shortfall (2a)</td>
</tr>
<tr>
<td>Remove PKE and reduce herd size (1b)</td>
<td>Reduce PKE feeding to 15% then reduce herd size (2b)</td>
</tr>
<tr>
<td>Reduce PKE feeding to 15% then realign (2c)</td>
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</table>

### High PKE users

**Farm1 (1.1tDM PKE/cow)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Strategy 1</th>
<th>Strategy 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Operating profit $/ha</td>
<td>-$398*</td>
<td>-$113</td>
</tr>
<tr>
<td>% change in greenhouse gases(GHG)</td>
<td>-4*</td>
<td>-17</td>
</tr>
<tr>
<td>% change in N leaching</td>
<td>-7*</td>
<td>-10</td>
</tr>
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</table>

### Farm2 (0.97tDM PKE/cow)

<table>
<thead>
<tr>
<th>Description</th>
<th>Strategy 1</th>
<th>Strategy 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Operating profit $/ha</td>
<td>-$357^</td>
<td>-$198</td>
</tr>
<tr>
<td>% change in GHG</td>
<td>-2^</td>
<td>-11</td>
</tr>
<tr>
<td>% change in N leaching</td>
<td>0^</td>
<td>-10</td>
</tr>
</tbody>
</table>

### Medium PKE users

**Farm3 (0.7tDM PKE/cow)**

<table>
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<tr>
<th>Description</th>
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<th>Strategy 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Operating profit $/ha</td>
<td>-$243*</td>
<td>-$111</td>
</tr>
<tr>
<td>% change in GHG</td>
<td>-3*</td>
<td>-11</td>
</tr>
<tr>
<td>% change in N leaching</td>
<td>-4*</td>
<td>-7</td>
</tr>
</tbody>
</table>

**Farm4 (0.56tDM PKE/cow)**

<table>
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<tr>
<th>Description</th>
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<th>Strategy 2</th>
</tr>
</thead>
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<tr>
<td>Change in Operating profit $/ha</td>
<td>-$99*</td>
<td>-$67</td>
</tr>
<tr>
<td>% change in GHG</td>
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<td>-11</td>
</tr>
<tr>
<td>% change in N leaching</td>
<td>-3*</td>
<td>-8</td>
</tr>
</tbody>
</table>

### Low PKE users

**Farm5 (0.25tDM PKE/cow)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Strategy 1</th>
<th>Strategy 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Operating profit $/ha</td>
<td>-$118*</td>
<td>-$100</td>
</tr>
<tr>
<td>% change in GHG</td>
<td>-1*</td>
<td>-6</td>
</tr>
<tr>
<td>% change in N leaching</td>
<td>-2*</td>
<td>-4</td>
</tr>
</tbody>
</table>

High PKE users

Farm1 (1.1tDM PKE/cow)

| Change in Operating profit $/ha | -$398* | -$113 | -$76* | -$31 | 0 |
| % change in greenhouse gases(GHG) | -4* | -17 | 0* | -3 | 0 |
| % change in N leaching | -7* | -10 | -2* | -3 | 0 |

Farm2 (0.97tDM PKE/cow)

| Change in Operating profit $/ha | -$357^ | -$198 | -$55^ | -$17 | $7 |
| % change in GHG | -2^ | -11 | 0^ | -1 | 0 |
| % change in N leaching | 0^ | -10 | -1^ | -1 | 0 |

Medium PKE users

Farm3 (0.7tDM PKE/cow)

| Change in Operating profit $/ha | -$243* | -$111 | -$47* | -$47 | -$8 |
| % change in GHG | -3* | -11 | 0* | -2 | 0 |
| % change in N leaching | -4* | -7 | -1* | -1 | 0 |

Farm4 (0.56tDM PKE/cow)

| Change in Operating profit $/ha | -$99* | -$67 | -$28* | -$25 | -$10 |
| % change in GHG | -2* | -11 | -1* | -4 | 0 |
| % change in N leaching | -3* | -8 | -1* | -3 | 0 |

Low PKE users

Farm5 (0.25tDM PKE/cow)

| Change in Operating profit $/ha | -$118* | -$100 | 0 | 0 | 0 |
| % change in GHG | -1* | -6 | 0 | 0 | 0 |
| % change in N leaching | -2* | -4 | 0 | 0 | 0 |
## Farm6 (0.2tDM PKE/cow)

Already feeding to compliance levels

<table>
<thead>
<tr>
<th></th>
<th>Change in Operating profit $/ha</th>
<th>% change in GHG</th>
<th>% change in N leaching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-$63*</td>
<td>-1*</td>
<td>-1*</td>
</tr>
<tr>
<td></td>
<td>-$29</td>
<td>-3</td>
<td>-2</td>
</tr>
</tbody>
</table>
Colostrum management practices affect failure of passive transfer, small intestine development, serum IGF-1, and feed conversion of dairy calves

P van Keulen\textsuperscript{a,b}, SA McCoard\textsuperscript{a}, J Dijkstra\textsuperscript{b}, and MA Khan\textsuperscript{a,*}

\textsuperscript{a}Animal Nutrition and Physiology Team, AgResearch Grasslands, Palmerston North 4442, New Zealand; \textsuperscript{b}Animal Nutrition Group, Wageningen University & Research, 6708 WD, Wageningen, the Netherlands

*Corresponding author. E-mail: ajmal.khan@agresearch.co.nz

Abstract

This study evaluated the effects of calf collection time postpartum and colostrum quality on failure of passive transfer (FPT), growth, and intestinal development of calves during pre-weaning. Forty newborn calves (Friesian×Jersey) were collected from the calving paddock either twice daily (within 12h postpartum; early n=20) or once daily (between 12-24h postpartum; late, n=20). Calves were fed either high-quality colostrum (HQC; %Brix = 22.7 ± 1.75) or low-quality colostrum (LQC; %Brix = 12.3 ± 0.98) for the first three (late calves) or four (early calves) feeds. All calves were fed and managed similarly for 35 d when they were slaughtered to study small intestine morphology. Feed intake and body weight of calves were recorded and feed conversion ratio (FCR; body weight gain: feed DM intake) was calculated. Blood samples were collected at d0, d4 and d35 for IGF-1 analysis and serum total protein was analysed to assess FPT (≤50 mg/ml) on d4. Feeding HQC reduced the prevalence of FPT, increased serum IGF-1 concentrations, increased surface area of small intestinal, and improved FCR compared with LQC feeding. Collection time had no effect on prevalence of FPT and surface area of small intestine. However, later collected calves had greater FCR compared with those collected earlier.

Keywords
dairy calves; colostrum; collection time; FPT; intestinal development; FCR

Introduction

Feeding good quality colostrum is vital to achieve desired serum levels of colostral antibodies in artificially-reared calves in order to protect them from disease and to prime their immune system (Weaver et al. 2000). Absorption of sufficient amounts of colostral antibodies determines if a calf is classified as having failure of passive transfer (FPT; Coleman et al. 2015), which has been associated with increased disease incidence (Todd et al. 2018), reduced growth rates until breeding (Cuttance et al. 2018a), and reduced lifetime performance (Faber et al. 2005)

In seasonal dairying, colostrum management is logistically challenging because calves are often only collected once daily from calving areas and fed colostrum of varying quality. Therefore, it is not surprising that Cuttance et al. (2017) reported, under New Zealand conditions, an overall prevalence of FPT of 33%, ranging between 5 to 80%. The FPT could negatively affect health and development of vital organs in calves (Steele et al. 2016). For example, various nutrients, peptides, hormones and growth promotors in colostrum has been shown to regulate cell proliferation of the small intestine (Blättler et al., 2001), which is essential for feed digestion, nutrient absorption, and protection against external pathogens (Blum, 2006). The objective of this study was to determine the effects of calf
collection time postpartum and colostrum quality on FPT and calf growth performance, and intestinal development in the first five weeks of life.

Material and Methods

This study was approved by the Animal Ethics Committee of AgResearch Grasslands (Approval #13942). Forty mixed-sex crossbred (Friesian×Jersey) newborn calves were sourced from two Massey University research farms. Farms were visited twice daily whereby newborn calves were identified with paint, and subsequently, calves were collected from the paddock either twice daily (within 12h postpartum; early) or once daily (between 12-24h postpartum; late). Brix value (%Brix), determined with refractometry for each colostrum feeding, was used as a quantitative measure for colostral antibodies according to Coleman et al. (2015). At arrival at the research facility, calves were fed either high-quality colostrum (HQC; %Brix = 22.7±1.8) or low-quality colostrum (LQC; %Brix = 12.3±1.0) for the first three (late calves) or four (early calves) feeds at 7.5% of their arrival BW (32.3±4.6 kg). Thereafter, all calves were fed LQC twice daily at 10% of their arrival BW on d3 and d4. After four days, all calves were fed 20% of their arrival BW/d of milk replacer (28% CP, 20% fat, Reliance Feeds; mixed at 125 g/L), which was individually recorded using automatic-feeders (CalfSmart, NZ). Pelleted calf starter (22% CP, SealesWinslow) and water were offered ad libitum.

All calves were weighed on arrival and then weekly, whereupon average daily gain (ADG) and feed conversion ratio (FCR; Body weight gain/ Feed DM intake) were calculated. Blood samples were taken from the jugular vein at arrival (d0, before colostrum feeding), d4 (after colostrum feeding was finished), and at the end of the trial (d35), and analysed for IGF-1 by DairyNZ (Hamilton, NZ). In addition, serum total protein concentrations were analysed to assess FPT (≤50 mg/ml) on d4 (Cuttance et al., 2018b). The calves were slaughtered at 35±2 d of age and duodenum, jejunum, and ileum samples were collected, fixed in formalin, and processed by the Histology Laboratory of Massey University (Palmerston North, NZ). Morphometric analysis (twenty villi/parameter) included villus height, width, and density, and the total absorptive surface area was calculated according to Kisielinski et al. (2002). Analysis was performed using a light microscope coupled with a digital camera (ProgRes C14, Jenoptik) to a computer with image processing software (Image-Pro 7.0, Media-Cybernetics). Data were analysed using a linear mixed model (R Core team, 2017) that included collection time, colostrum quality, and their interaction as fixed effects, calf as a random effect, and week as repeated measurement. Values are presented as least-square means ± SEM and effects were significant at P≤0.05.

Results and Discussion

Calf collection time did not affect FPT, with 30% of early vs. 26% of late collected calves failing to acquire sufficient colostral antibodies at d4 (P=0.56). Neither once or twice daily collection of calves was able to prevent FPT and almost one third of the calves had FPT, which is in agreement with other studies performed in the NZ pastoral system (Cuttance et al. 2017; Lawrence et al. 2017). Feeding HQC after arrival into the rearing facility reduced FPT to a level of 10% by d4 (P<0.001), as compared with 47% in calves fed LQC. A trend (P=0.08) towards an increased ADG was observed in HQC vs. LQC calves (665 vs. 590 g/d). Calves receiving HQC tended (P=0.09) to be 2.5 kg heavier over the experimental period, but weight at 35 d was not influenced by postpartum collection time (P=0.56).

The interaction between collection time and colostrum quality was not significant (P>0.10) for FCR, however calves fed HQC had greater (P=0.03) FCR compared with those fed LQC (Fig. 1) and calves collected once daily had greater (P=0.01) FCR compared with those collected twice daily. Calves fed HQC had greater total surface area in the duodenum (+28%; P=0.04) and jejunum (+21%; P=0.02), with a similar trend in the ileum (+13%; P=0.09), as compared to calves fed LQC (Fig. 1). Collection time
postpartum had no effect ($P>0.10$) on total surface area in the duodenum, jejunum and ileum and the interactions between collection time and colostrum quality were not significant ($P>0.10$) for surface area of small intestine. Positive effects of feeding high-quality colostrum on small intestine development in calves have been previously demonstrated in literature (Bühler et al., 1998; Blättler et al., 2001). Similarly, greater development of villi in various intestinal segments of HQC than LQC fed calves increased absorptive surface area, which is important for nutrient absorption efficiency to enhance FCR and ADG.

**Fig. 1.** Intestinal surface area of the duodenum, jejunum, and ileum (left y-axis) and feed conversion ratio (FCR; body weight gain:feed DM intake; right y-axis) of 35-d-old calves fed low-quality colostrum (LQC) or high-quality colostrum (HQC) after arrival at the facility within 24h postpartum.

Serum IGF-1 concentrations were greater (+80%; $P<0.001$) in HQC than LQC fed calves on d4, but not on d0 and d35, and was not affected by time of collection. Greater serum IGF-1 concentration in calves that received HQC vs. LQC is in agreement with previous findings (Rauprich et al., 2000), where IGF-1 markedly increased in calves which received the first milking colostrum compared to those that received water or milk replacer. Colostral IGF-1 aids intestinal development in neonatal calves (Baumrucker et al., 1994), which is in agreement with findings of the current study. Furthermore, feeding first-milking colostrum within 24h after birth triggers the endogenous production of IGF-1 and modulates the somatotropic axis, which results in a systemic effect improving utilisation of nutrients for growth (Hammon and Blum, 1997).

In conclusion, in comparison to feeding LQC, feeding HQC within 24h after birth, reduced the prevalence of FPT, increased serum IGF-1 concentrations at d4, increased the surface area of the small intestine, and greater FCR during the first five weeks of calf age. However, earlier vs. later collection of calves after birth from calving paddock had shown no effect on prevalence of FPT and surface area of small intestine however; calves collected once daily had greater FCR compared with those collected twice daily. Therefore, farmers in seasonal pastoral dairying systems should offer calves high-quality colostrum to reduce the prevalence of FPT.
Acknowledgements

This research was funded by AgResearch’s Strategic Science Investment Fund. The authors gratefully acknowledge the Animal Nutrition and Physiology staff and Grasslands Research Centre Animal Facility staff for their involvement in the care of the animals and collection of the tissue samples.

References


Selecting cattle for low residual feed intake did not affect daily methane production, but increased methane yield.

HE Flay¹, B Kuhn-Sherlock¹, KA Macdonald¹, M Camara³, N Lopez-Villalobos², DJ Donaghy² and JR Roche¹,³,⁴*

¹DairyNZ Limited, Newstead, Private Bag 3221, Hamilton, New Zealand 3210.
²School of Agriculture and Environment, Massey University, Palmerston North, New Zealand 4410.
³School of Biological Sciences, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand.
⁴Current address: Ministry for Primary Industries, Pastoral House, Wellington, New Zealand.
*Corresponding author. Email: john.roche@mpi.govt.nz

Short Title: Feed Efficiency and Methane

Abstract
Enteric methane (CH₄) is an important source of digestible energy loss in ruminants. We hypothesised that low residual feed intake (RFI) dairy heifers, which are more feed efficient, would produce less CH₄. We measured daily CH₄ production (g/d), CH₄ yield (g/kg DMI), and CH₄ per body weight (BW) gain (BWg) for 56 pregnant heifers (20-22 mo old) in a 2 x 2 factorial arrangement: factors included breed (Holstein-Friesian and Jersey; n=28/breed) and RFI category, either high (+2.0 kg DM/d) or low (-2.1 kg DM/d; n=28/RFI category). RFI category did not affect heifer BW or BWg, but low RFI heifers had significantly lower DMI and DMI/kg BW. RFI category did not affect CH₄/d or CH₄/kg BWg; but, CH₄/kg DMI was greater in low RFI heifers because of their lower DMI. The increased methane yield in low RFI heifers potentially reflects more complete digestion of ingested feed in these animals, consistent with previous reports of greater apparent digestibility of organic matter in low RFI cows. Holstein-Friesian heifers were heavier, consumed more total DM, and produced more CH₄/d. However, breed did not affect CH₄/kg DMI or CH₄/kg BWg. In conclusion, selecting dairy heifers for low RFI is unlikely to affect daily CH₄ production (g/d), and may increase CH₄ yield (g/kg DMI).

Keywords
feed conversion efficiency, environmental sustainability, greenhouse gas

Introduction
Rapid growth in human populations and concomitant rising demand for animal products are generating concerns that enteric CH₄ emissions are contributing to climate change (Garnsworthy et al. 2012; Huhtanen et al. 2015). Reducing these emissions, while maintaining current production, requires improved feed conversion efficiency (FCE; Waghorn et al., 2012; Potts et al., 2015). Ruminants eruct 5-10% of their gross energy intake as CH₄ (van Soest 1994). Selective breeding for
more feed efficient animals could both reduce CH\textsubscript{4} emissions and increase productivity. Residual feed intake is a measure of FCE that describes the difference between an animal's actual DMI and its predicted DMI for maintenance and production. Residual feed intake has been positively associated with daily CH\textsubscript{4} production in beef steers (i.e. low RFI animals produced less CH\textsubscript{4}/d; Nkrumah et al., 2006; Hegarty et al., 2007; Fitzsimons et al., 2013). Differences in FCE have been reported between breeds, with Jersey (Jer) cows requiring less feed/kg of milk components produced than Holstein-Friesian (HF) cows (L'Huillier et al., 1988; Prendiville et al., 2009; Spaans et al., 2018). This is probably due to the comparatively larger gastrointestinal tract of Jer cows, promoting an increase in NDF and DM digestibility (Beecher et al. 2014). Therefore, it is plausible that these breeds differ in CH\textsubscript{4} production and CH\textsubscript{4}/kg DMI. We hypothesised that high feed efficient (low RFI) heifers would emit less CH\textsubscript{4}/kg DMI than high RFI heifers, and that Jer heifers would have lower CH\textsubscript{4} yield than HF heifers.

**Materials and methods**

We measured daily CH\textsubscript{4} production in a 2 x 2 factorial arrangement of breed and pre-defined RFI category: 28 Holstein-Friesian and 28 Jersey pregnant heifers (20-22 mo old) previously identified as high RFI (+2.0 kg DM/d) or low RFI (-2.1 kg DM/d; n = 14/treatment). The Ruakura Animal Ethics Committee (Hamilton, New Zealand) approved all animal manipulations in accordance with the New Zealand Animal Welfare Act (1999). The experiment was undertaken at Lye Farm, Hamilton, New Zealand (37°46’S 175°18’E) between March and June 2017.

The heifers were split into two cohorts and housed in a free-stall facility for approximately 30 d with unrestricted access to dried lucerne cubes from feeding stations, from which feed disappearance was electronically measured and the volume of exhaled gas measured and sampled for real-time CH\textsubscript{4} analysis (C-Lock Inc., Rapid City, SD, USA). Mean daily DMI and CH\textsubscript{4} emissions were calculated for each animal. Dependent variables were analyzed using a linear model that included the effects of breed, RFI category, their interaction, and cohort as blocking factor. Statistical analyses were performed using R (version 3.3.3, R Core Team, 2017). Results are presented as least-squares means and standard error of the difference, and significance was declared if P≤0.05.

**Results and discussion**

Average CH\textsubscript{4}, DMI, and BWg summary data are presented in Table 7. Breed x RFI category interactions were not significant. RFI category had no significant effect on BW or BWg, but DMI and DMI/kg BW were 9.3% and 10.6% lower, respectively, in low RFI compared with high RFI heifers. RFI category had no effect on CH\textsubscript{4}/d or CH\textsubscript{4}/kg BWg. However, low RFI heifers had a 9.7% greater CH\textsubscript{4}/kg DMI than heifers in the high RFI category because of their lower DMI. Therefore, our results do not support our hypothesis that low RFI animals would have lower enteric CH\textsubscript{4} emissions.
Table 6. Least square means for groups representing two breeds (Holstein-Friesian: HF; and Jersey: Jer, n=28/breed) and two pre-determined residual feed intake (RFI)\(^1\) categories (Low: -2.1 kg DMI/d and High: +2.0 kg DMI/d, n=28/RFI category). Animals were 20-22 mo old pregnant dairy heifers and were offered unlimited access to dried lucerne cubes.

<table>
<thead>
<tr>
<th></th>
<th>Breed</th>
<th>RFI category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jer</td>
<td>HF</td>
</tr>
<tr>
<td>BW(^2), kg</td>
<td>408</td>
<td>480</td>
</tr>
<tr>
<td>DMI, kg DM/d</td>
<td>11.3</td>
<td>12.4</td>
</tr>
<tr>
<td>DMI, kg DM/BW(^{0.75})</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>BWg(^3), kg/d</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>CH(_{4}), g/d</td>
<td>242</td>
<td>267</td>
</tr>
<tr>
<td>CH(_{4}), g/DMI</td>
<td>21.6</td>
<td>21.9</td>
</tr>
<tr>
<td>CH(_{4}), g/kg BWg</td>
<td>220</td>
<td>212</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>BW(^2), kg</td>
<td>448</td>
<td>439</td>
</tr>
<tr>
<td>DMI, kg DM/d</td>
<td>11.3</td>
<td>12.4</td>
</tr>
<tr>
<td>DMI, kg DM/BW(^{0.75})</td>
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<td>0.13</td>
</tr>
<tr>
<td>BWg(^3), kg/d</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>CH(_{4}), g/d</td>
<td>253</td>
<td>256</td>
</tr>
<tr>
<td>CH(_{4}), g/DMI</td>
<td>22.7</td>
<td>20.7</td>
</tr>
<tr>
<td>CH(_{4}), g/kg BWg</td>
<td>224</td>
<td>207</td>
</tr>
</tbody>
</table>

\(^1\) The RFI is the difference between amount of feed in kg DM required for biological processes and measured feed

\(^2\) BW = average BW estimated as the predicted BW at the midpoint of the experiment.

\(^3\) BWg = average daily BW gain

These results indicate that differences in ruminal digestive efficiency may explain the greater FCE in low RFI heifers. If lower RFI is a result of greater ruminal feed digestibility, particularly NDF digestibility in a high forage diet, this would be expected to increase CH\(_{4}\)/kg DMI (Moate et al. 2016). This is consistent with the previously reported greater physical breakdown of feed (Gregorini et al. 2015) and the higher apparent digestibility of organic matter (Rius et al. 2012) in low RFI animals.

Previously reported effects of RFI on enteric CH\(_{4}\) production in cattle are limited to beef animals. Most studies report a positive relationship between RFI and both DMI and CH4/d (Nkrumah et al. 2006; Hegarty et al. 2007; Fitzsimons et al. 2013); however, the effect of RFI on CH\(_{4}\)/d is not consistent (McDonnell et al. 2016). The reason for the inconsistent effects of RFI on CH\(_{4}\) production between our study and previous beef cattle research is not known, but it might relate to differences in diet, gender, age or physiological state.

Breed affected BW, DMI, and CH\(_{4}\) production. HF heifers were heavier and consumed more than Jer heifers, with similar BWg between breeds. HF heifers produced about 10.3% more CH\(_{4}\)/d than Jer heifers due to their greater DMI. However, breed did not affect CH\(_{4}\)/kg DMI or CH\(_{4}\)/kg BWg. The lack of breed effect on CH\(_{4}\) yield in our study is consistent with previous reports, despite a reported greater FCE of Jer animals (Goddard and Grainger 2003). Further research is required to understand the mechanisms supporting the greater FCE in Jer animals. Our data indicate that dairy...
breed does not affect CH$_4$ yield (g/kg DMI) and any difference in daily CH$_4$ production are associated with differences in DMI.

**Conclusion**

Selecting dairy heifers for low RFI did not reduce total daily CH$_4$ production because, despite a lower DMI, these animals produced more CH$_4$/kg DMI. In addition, HF heifers produced more CH$_4$ on a daily basis (g/d) due to increased DMI, but there was no effect of breed on methane yield (g/kg DMI).

**Acknowledgements**

The authors acknowledge all the help afforded them by Lye Farm staff and the technical support of Olivia Jordan and Mark Bryant. This research was funded by the New Zealand Government to support the objectives of the Livestock Research Group of the Global Research Alliance on Agricultural Greenhouse Gases.

**References**


Table 7. Least square means for groups representing two breeds (Holstein-Friesian: HF; and Jersey: Jer, n=28/breed) and two pre-determined residual feed intake (RFI) categories (Low: -2.1 kg DMI/d and High: +2.0 kg DMI/d, n=28/RFI category). Animals were 20-22 mo old pregnant dairy heifers and were offered unlimited access to dried lucerne cubes.

<table>
<thead>
<tr>
<th>Breed</th>
<th>RFI category</th>
<th>SED</th>
<th>P-val</th>
<th>SED</th>
<th>P-val</th>
</tr>
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<tbody>
<tr>
<td>Jer</td>
<td>Low</td>
<td>448</td>
<td>4.2</td>
<td>8.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HF</td>
<td>High</td>
<td>439</td>
<td>8.2</td>
<td>&lt;0.001</td>
<td>0.268</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Breeding</th>
<th>RFI category</th>
<th>SED</th>
<th>P-val</th>
<th>SED</th>
<th>P-val</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW 2, kg</td>
<td>Low</td>
<td>408</td>
<td>8.2</td>
<td>&lt;0.001</td>
<td>448</td>
</tr>
<tr>
<td>DMI, kg DM/d</td>
<td>High</td>
<td>439</td>
<td>8.2</td>
<td>&lt;0.001</td>
<td>0.003</td>
</tr>
<tr>
<td>DMI, kg DM/BW 0.75</td>
<td>Low</td>
<td>0.12</td>
<td>0.003</td>
<td>0.003</td>
<td>0.12</td>
</tr>
<tr>
<td>BW 3, kg/d</td>
<td>High</td>
<td>1.3</td>
<td>0.08</td>
<td>0.077</td>
<td>1.3</td>
</tr>
<tr>
<td>CH 4, g/d</td>
<td>Low</td>
<td>6.2</td>
<td>&lt;0.001</td>
<td>6.2</td>
<td>0.596</td>
</tr>
<tr>
<td>CH₄, g/DMI</td>
<td>21.6</td>
<td>21.9</td>
<td>0.64</td>
<td>0.623</td>
<td>22.7</td>
</tr>
<tr>
<td>CH₄, g/kg BWg</td>
<td>220</td>
<td>212</td>
<td>13.8</td>
<td>0.598</td>
<td>224</td>
</tr>
</tbody>
</table>

1 The RFI is the difference between amount of feed in kg DM required for biological processes and measured feed.

2 BW = average BW estimated as the predicted BW at the midpoint of the experiment.

BWg = average day
Dairy Farm Strategy in a Volatile, Uncertain, Complex and Ambiguous World

J.S. Bircham
PO Box 11179 Palm Beach 3151

Abstract

Volatility, uncertainty, complexity and ambiguity are hallmarks of an emerging world, one in which the dairy industry will find itself confronted by a plethora of regulations and imperatives of global and national origin; one in which strategic and operational adaptability and agility will be required. A simulator approach to strategy formulation and evaluation is proposed, an approach that could also underpin the ongoing education and training of unskilled and inexperienced workers.

Introduction

For many decades, prior to the early 1990s, there was little need for the temperate grassland dairy farmer to evaluate the merits of their current strategy, let alone formulate a new one. Once decisions had been made on next year’s stock numbers (up or down), calving date (forward or back), fertiliser and cropping/conservation program, etc., their strategy and modus operandi was, very simply, more of the same, responding as necessary to the vagaries of the market and the climate. Notwithstanding the advent of globalization and an increasingly VUCA (volatile, uncertain, complex & ambiguous) world (Gruwez, 2017), today’s dairy farmers also find themselves having to contend with a plethora of political, economic, societal and environmental regulations and imperatives, that not only impact productivity and profitability, but also their modi operandi. VUCA is the new norm.

Moreover, concurrent with this rising tide of regulations and imperatives, has been the emergence of a hidden and largely unrecognised reality, that of a scarcity of experienced and skilled workers (Hutching, 2018); leaving many farmers with no choice but to employ inexperienced and unskilled workers; and the necessity to also educate and train them.

Knowledge Acquisition

Loss of knowledge, both explicit and tacit, is an outcome of merging what were once generationally owned and operated farms into bigger units, staffed by workers who have little or no local knowledge or farm experience. Explicit knowledge, that which is based on codification, rules, process, etc., is relatively easy to transfer. Tacit knowledge, however, that which is based upon personal experiences, insights, intuition, observations and internalized information (“we know more than we can tell”, Polanyi, 1966, p 4) is more difficult to transfer. Traditionally, the tacit knowledge of one generation, acquired through their experience, has been articulated and codified into explicit knowledge and then passed down to the next generation, internalized by them and, then in turn, passed down to ensuing generations. This flow of knowledge from the tacit to explicit not only created or enhanced both individual and inter-generational knowledge (Nonaka and Takeuchi, 1995), it also built and enhanced inter-generational resilience.

Simulator Approach

The aviation industry has used “flight simulators” to train air-crew for decades, not only to impart and refine the knowledge (explicit & tacit) and skills required to fly an aircraft, but also to expose them to situations that require adaptive and agile responses, thereby imparting experience and thence knowledge.
The learning objective for a simulated flight, by way of example, could be to familiarise a crew with a new route and destination or to confront them with in-flight circumstances that require adaptive and agile responses. Once a “flight plan” has been filed, the responsibilities of the crew include ensuring that the aircraft is adequately provisioned for the flight, flying the aircraft in accordance with the flight path filed in the flight plan and negotiating any adverse weather conditions encountered en route.

deCida\textsuperscript{2}, a purpose-built dairy-farm simulator, embraces the “flight simulator” approach to learning, and the acquisition and transfer of both explicit and tacit knowledge. It too requires a plan, a farm plan (flight plan), inclusive of production targets, farm average pasture cover (the farm’s flight path) and policies for stock, fertiliser nitrogen, cropping/conservation and supplementary feeding. The feed required to realise a farm plan’s production targets (provisioning) is determined before assessing whether or not pasture growth (rainfall and temperature driven), available pasture mass and supplement inputs are sufficient to meet, not meet (feed deficit) or exceed (pasture surplus) stock feed requirements (figure 1). Farm average pasture cover is used to manage a farms metaphoric flight path (i.e. the accumulation and utilisation of pasture mass) and rainfall and temperature profiles are used to mediate (through pasture growth inputs) the effects (impacts) of the vagaries of weather.

![Figure 1: deCida - Strategy Mode Output for Spring Calving Herd](image)

Pasture conditions, principally pasture mass and sward height in temperate grasslands, mediate the continuous and dynamic interaction between plant and grazing animal that is intrinsic to the grazed temperate grassland ecosystem, as both plant, animal grazing behaviour and performance can be related to prevailing pasture conditions (Bircham 1984; Forbes, 1987; Hodgson 1989; Milligan 1987). Pre-graze pasture conditions can limit bite size compared to that possible under more favourable pasture conditions, the grazing animal’s response being to reduce bite size, increase its rate of biting and to extend the time it spends grazing. Rotational grazing systems, however, can curtail
such compensatory grazing behaviour, the outworking of which is “small bite sized induced feed deficits”, reduced daily intake and production. In deCida, the proxy for pasture condition is pre-graze pasture cover.

In “strategic” mode, deCida uses average pasture cover to guide high-level decision making on stock, fertiliser nitrogen, cropping/conservation and supplementary feeding policies, and in “operational” mode it guides everyday resource allocation (size of day & night pasture breaks, supplementation required, etc.) for herds with varying nutritional requirements (e.g. dries, springers, milkers).

It is the use of the average pasture cover dynamic implicit in the pasture-animal interface, rather than an abstract artefact such as “rotation length” or “pasture allowance/offer”, to both assess the state of the grazed ecosystem and to also manage it, that sets deCida apart from spreadsheet driven feed budgets and many extension products based on research models.

Strategy – A Continuous & Evolving Process

Farm strategy formulation and evaluation is an evolving and never-ending process (Milligan, 1987), not an annual one-off exercise. This refining process is necessary to accommodate not only the vagaries of climate, but also the changes to stock, fertiliser, cropping/conservation and supplement policies that invariably occur. Moreover, as seasons unfold, threats to the achievement of objectives, irrespective of their origin, become more apparent, as do opportunities. To be able to foresee emerging threats, long before they become reality, and to have the time to provision contingency measures should they become necessary, is one of the many benefits of continuous strategic review.

Equally as important as the ongoing development and refining of strategy that a VUCA world demands, is the need to address the increasing loss of tacit and explicit knowledge from the dairy industry. Simulators, like deCida, with their capability to underpin learning, knowledge acquisition and resilience enhancement, have the potential to redress, at least in part, this loss.

In summary, a dairy-farm simulator provides a quick and easy way of fleshing-out and refining farm resourcing and system ideas/strategies without having to commit real-resources or to make expensive mistakes. If the ideas/strategies evoked by an idea/insight do not stack up, irrespective of the reason, nothing is lost. In fact, there is gain, learning; knowledge that an idea/strategy does not stack-up in a particular context. In a VUCA world, such knowledge could be the difference between the success and failure of a dairy enterprise.

References


*Notes:* 1/ *deCida* - Portuguese for decide, make up your mind.
Reaching recommendations – a participatory approach to refining and prioritising future extension delivery in the Tasmanian dairy industry

Alison Hall¹, Lydia Turner¹ and Sue Kilpatrick²

¹ Tasmanian Institute of Agriculture, University of Tasmania
² Faculty of Education, University of Tasmania

Introduction

A key focus of extension in the Tasmanian dairy industry has been to increase implementation of pasture management practices and subsequent increase in pasture production, through supporting development of farmer knowledge, skills and confidence. Despite this focus, average pasture utilisation on Tasmanian dairy farms is still well below potential (Dairy Australia 2015). Significant variation exists in adoption and adaptation of pasture management practices, and in the extent farmers engage with extension activities (Hall et al. 2017), suggesting that changes could be made to extension programs to improve future engagement and adoption.

Adoption and practice change as an outcome of extension is a social process, influenced by personal and social factors (Pannell et al. 2006; Wauters and Mathijs 2010). Individual characteristics that impact extension engagement include education, social networks, farm business characteristics, activity type and learning environment (Fulton et al. 2003). To be successful in achieving practice change, extension programs require a variety of delivery methods and training options to cater for individual preferences (Kilpatrick 1996). To increase success, a participatory process, including farmers in information research and extension methods and outcomes, is suggested (Pannell et al. 2006). Understanding farmers’ attitudes, beliefs and social environment through social research is essential for effective design and targeting of extension activities.

Research aims and methods

This study drew on findings of two preceding studies. Responses (n=162) to a survey sent to all 440 Tasmanian dairy farmers identified past and current pasture management practices, and extent of extension engagement. In-depth interviews with 30 of these farmers, categorised into three sub-groups based on past and current use of pasture measurement tools and extension engagement (Table 1), explored why and how social factors influence pasture measurement tool and practice use, and decisions to engage with extension. Preliminary recommendations for future extension activities were informed by the survey and interviews, and tested using a modified Delphi technique.

Table 1. Sub-groups, number of farmers, and their characteristics

<table>
<thead>
<tr>
<th>Sub-groups</th>
<th>No. farmers interviewed</th>
<th>No. farmers surveyed</th>
<th>Engaged in extension</th>
<th>Been through intensive period of measuring pasture</th>
<th>Use of recommended pasture management practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unengaged</td>
<td>8</td>
<td>8</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Triallers</td>
<td>12</td>
<td>11</td>
<td>✓</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Adapters</td>
<td>10</td>
<td>8</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

The Delphi technique is a method designed to obtain consensus of opinions of groups of people, by using a series of typically two to three questionnaires (Dalkey and Helmer 1963). The first round typically consists of an open-ended questionnaire designed to solicit information on a content
area (Hsu and Sandford 2007). Subsequent rounds consist of questionnaires based on responses of the previous round (von Ruschkowski et al. 2013). Advantages of this method include the ability to maintain participant anonymity, control feedback, replace the need to meet physically in one location, and reduces bias and influence of responses that can occur in group settings (Dalkey and Helmer 1963).

In this participatory approach, the preceding farmer survey and interviews filled the role of initial questionnaires in a traditional Delphi technique. The final participatory survey, using the Delphi technique, was based on the initial survey and interview data and comprised 15 questions relating to preliminary recommendations about future extension design. Participants were asked to respond on a 5-point Likert scale of ‘strongly disagree’ to ‘strongly agree’ with responses indicating level of support for the recommendations. The survey was mailed to the 30 farmers who had participated in the preceding interviews (response rate of 90%). Surveys were coded and responses allocated to sub-groups. Due to the small sample size, ‘strongly agree’ and ‘agree’ responses were aggregated, and ‘strongly disagree’ and ‘disagree’. The response ‘neither disagree or agree’ was ‘neutral’. While complete statistical analysis was unable to be conducted due to sample size, analysis of responses was able to produce agree, disagree or neutral trends for each question for each sub-group. These indicate the level of support for associated recommendations.

**Results and discussion**

A participatory method based on the Delphi technique effectively prioritised recommendations for future extension activities for three farmer sub-groups (Table 2). Recommendations were generally supported, with most farmers in each sub-group responding ‘strongly agree’ to associated questions. Weaker ‘agree’, ‘neutral’ and ‘disagree’ responses indicated that some recommendations are of lower priority for future extension. For example, farmer responses suggest that using a guest speaker would be more effective for engaging Triallers than the other sub-groups.

**Table 2.** Recommendations for future extension, survey questions relating to recommendations, and extent of support for recommendations within three farmer sub-groups.

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Supported, not supported, neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduce different levels of pasture management training for farmers who have been through an intensive period of measuring previously, and those who haven’t</td>
<td>Unengaged – Supported Triallers – Supported Adapters – Supported</td>
</tr>
<tr>
<td>Introduce ‘master classes’ or activities with an ‘advanced pasture management’ component for farmers who consider themselves as experienced</td>
<td>Unengaged – Supported Triallers – Supported Adapters – Supported</td>
</tr>
<tr>
<td>Requirement for ongoing, on-farm support to understand and apply pasture measurement information, not just providing data</td>
<td>Unengaged – Supported Triallers – Supported Adapters – Supported</td>
</tr>
<tr>
<td>Identify and target motivating values for different farmer segments – e.g. for farmers motivated by animal care versus profitability</td>
<td>Unengaged – Supported Triallers – Supported Adapters – Neutral</td>
</tr>
<tr>
<td>Introduce a range of extension activities and group types (small groups, one on one)</td>
<td>Unengaged – Supported Triallers – Supported Adapters - Neutral</td>
</tr>
<tr>
<td>Introduce a range of activities, some focused on individual farm data and others that reduce this requirement</td>
<td>Unengaged – Neutral Triallers – Neutral Adapters – Not supported</td>
</tr>
<tr>
<td>Use an expert guest speaker</td>
<td>Unengaged – Neutral</td>
</tr>
</tbody>
</table>
This study confirmed and prioritised relevant recommendations for future extension approaches for each sub-group. A key recommendation to encourage the Unengaged sub-group to participate in extension is identifying and targeting their motivating values, such as focusing on the benefits of improved pasture management on cow health and performance. Further research to increase our understanding of these values that influence farmer decision making would provide valuable information to guide this extension development.

A key recommendation for Triallers is introducing different levels of pasture management training. The Triallers see themselves as experienced pasture managers, despite not having progressed through an intensive learning process or using recommended pasture management practices (Hall et al. in press). As Triallers believe that existing pasture management training is more applicable to younger, or less experienced farmers, designing and marketing ‘Master Classes’ may encourage them to re-engage in the learning process.

The Adapters are more flexible in regards to extension design, indicated by the general neutral response to questions on activity type and content. They are currently engaged with extension, indicating less focus is required on changing current activities.

Conclusion

Understanding social factors influencing farmer engagement is essential if future extension activities are to facilitate increased adoption and practice change. A participatory method using survey and interview data to refine final survey questions to farmers enabled greater insight into targeting future extension activities to different farmer sub-groups knowledge, skills and values. The final survey prioritised recommendations for farmer sub-groups, with the method successfully allowing farmers the opportunity to provide equally weighted feedback. Farmer responses provide an evidence-based foundation to inform design of future extension content, marketing and delivery that will attract and engage a wider range of farmers by addressing and catering for farmer preferences, skills and values.

References


Effect of winter crop and dry matter allocation on colostrum quality of dairy cattle

Dawn Dalley1*, Paul Edwards1, Jane Kay2, Willis Ritchie3, Nicole S Hammond3

1 DairyNZ, PO Box 85066, Lincoln University, 7647, New Zealand.
2 DairyNZ, Hamilton, 3240, New Zealand.
3 DairyNZ, Invercargill, 9810, New Zealand.

*Corresponding author. Email: dawn.dalley@dairynz.co.nz

Abstract

Increased health issues and perceived underperformance of dairy cattle in fodder beet feeding systems has raised concerns about potential negative cumulative effects of diets containing fodder beet. During winter 2017, 320 mixed-age cows were assigned to four treatments (80/treatment) at the Southern Dairy Hub, in Southland, New Zealand, to investigate early lactation performance of cows wintered on kale or fodder beet (FB). Immediately prior to the first milking following calving, foremilk samples were collected from each quarter of each cow and a Brix measurement made to assess colostrum quality.

Average Brix% did not differ significantly between treatment groups but there was high variation between cows and quarters within cows. Cows wintered on FB had a numerically higher proportion of samples with a Brix% ≥22 (adequate quality) at the time of sampling as compared with cows wintered on kale. It is unknown if the colostrum quality ranges observed were due to variation in calf colostrum removal prior to sampling, the volume of colostrum produced or to the nutrition of the dam during winter.

Keywords

fodder beet, kale, brix value, colostrum quality

Introduction

Winter-grazed forage crops continue to be an important aspect of farming in southern regions of New Zealand. Brassica crops (e.g. kale, turnips, and swedes) and fodder beet (FB) are an essential source of winter feed on farms in the southern regions of NZ (Nichol et al., 2003; Dalley, 2010), with FB use increasing exponentially in recent years (Waghorn et al., 2018). Following this rapid increase, farmers and veterinarians are becoming increasingly concerned about negative carryover effects on animal performance. Increased body condition score at calving in cows wintered on FB has resulted in
more metabolic disease (e.g. milk fever and liver dysfunction at parturition) and farmers and veterinarians have reported less udder development immediately prior to calving in cows wintered on fodder beet. Both these factors could impact on the amount and quality of colostrum produced.

To ensure good health and future production potential, newborn calves need to absorb sufficient immunoglobulins (IgG) via the ingestion of colostrum, during the first 24 hours of life (Weaver et al., 2000). The concentration of IgG in colostrum varies according to many factors including a cow’s health history, volume of colostrum produced, age of cow and breed (Gulliksen et al. 2008). The gold standard test for measuring IgG in colostrum, radial immunodiffusion, is expensive and technically difficult to measure, so IgG is often indirectly assessed using a Brix refractometer (Bielmann et al. 2010; Quigley et al. 2013). Concentrations of IgG ≥50g/L, equivalent to Brix values of ≥22, are considered to indicate good quality colostrum (Bielmann et al. 2009; Quigley et al. 2013). The purpose of the experiment was to determine if winter crop type and dry matter (DM) allocation affected colostrum quality, as assessed with Brix%, in mixed-aged cows at their first milking.

Materials and methods

In May 2017, 320 mixed-aged Friesian-cross cows were randomly allocated to four treatments in a 2x2 factorial design comparing two crop types (FB or kale) and two levels of DM allocation (target for 0.7 body condition score unit gain (Target) or ad libitum (Ad Lib)). Treatments were balanced for age (4.6 ± 0.09 years), expected mean calving date (22 Aug 2017 ± 2.0 days) and breeding worth (91 ± 1.99). Cows were transitioned onto their winter diet following recommended good management practice for each crop type. Ten days before expected calving date the cows were drafted off crop and offered 10 kg DM of a combined pasture and baleage diet until calving.

During calving calves were removed from the dams once per day in early afternoon. Prior to the first milking a foremilk sample was collected from each quarter of all cows and stored frozen (Bielmann et al. 2010). Quarters that visually exhibited signs of suckling were included and noted. Following the completion of calving, samples were removed from the freezer and thawed, whereupon a Brix refractometer (Digital Brix/RI Check, Reichert Technologies Analytical Instruments) was used to measure colostrum quality (Brix%).

Results were analysed using REML variance components analysis in GenStat with Brix% as the response variate and crop type, DM allocation, and their interaction as modelling factors. The proportion of cows with a mean Brix value of ≥22 was analysed using generalised linear models with a binomial error distribution.

Results

There was no significant difference in mean Brix% between treatment groups (Table 1). Numerical differences were observed in the proportion of cows from each treatment with an average
Brix% ≥ 22, however, high between-cow variability resulted in these differences being statistically non-significant (Table 1). Numerically more cows on the Ad Lib feed allocation and FB treatments had a mean Brix% greater than 22. Crop type did not affect mean BCS at calving (P=0.32), however cows offered Ad Lib allowances were in better BCS at calving (P=0.03). There was no difference in the incidence of metabolic disorders at calving between the treatment groups.

Table 1. Crop and supplement allocation, targeted metabolizable energy intake (MEI), pre-calving body condition score (BCS), ad colostrum quality of cows wintered on kale or fodderbeet at a target DM allocation for 0.7 BCS gain (Target) or ad libitum (Ad Lib) for 8 weeks.

<table>
<thead>
<tr>
<th>DM allocation (kg/cow/d)²</th>
<th>Kale Target</th>
<th>Kale Ad Lib</th>
<th>Fodderbeet Target</th>
<th>Fodderbeet Ad Lib</th>
<th>SED</th>
<th>Diet Diet×DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kale</td>
<td>10.4</td>
<td>14.0</td>
<td>0.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fodderbeet</td>
<td>0.0</td>
<td>0.0</td>
<td>9.1</td>
<td>11.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Baleage</td>
<td>4.5</td>
<td>2.9</td>
<td>4.5</td>
<td>2.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>14.9</td>
<td>16.9</td>
<td>13.6</td>
<td>14.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Targeted MEI (MJ/cow/d)²</td>
<td>140</td>
<td>160</td>
<td>140</td>
<td>160</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pre-calving BCS</td>
<td>5.06</td>
<td>5.12</td>
<td>5.07</td>
<td>5.18</td>
<td>0.03</td>
<td>0.32</td>
</tr>
<tr>
<td>Average Brix%</td>
<td>21.6</td>
<td>22.9</td>
<td>22.2</td>
<td>23.1</td>
<td>1.08</td>
<td>0.61</td>
</tr>
<tr>
<td>Proportion of Brix% ≥22</td>
<td>0.45</td>
<td>0.53</td>
<td>0.53</td>
<td>0.57</td>
<td>0.05</td>
<td>0.26</td>
</tr>
</tbody>
</table>

¹The effect of winter crop (diet), dry matter allocation (DM), and their interaction (Diet × DM) are presented.
²Dry matter allocation to achieve the required ME intake was based on estimated feed quality and the assumptions of 85% utilisation of the kale and baleage, and 95% utilisation of fodder beet.

Discussion

Average Brix% at the first milking exceeded the 22% threshold for all treatments except the Target kale treatment. Denholm et al. (2017) reported that only 10% of pooled colostrum samples from commercial farms in New Zealand had a Brix% of ≥22 and attributed this to pooling first milking colostrum with later milking’s, once-daily collection of calves, and herd vaccination.

Brix values indicate that not all cows were producing colostrum of suitable quality for newborn calves and that, at the time of sampling, 6% more kale cows had Brix values less than 22. Although cows and calves were collected at the same time each day the amount of colostrum suckled by the calf would have varied based on time between birth and collection and the suckling behaviour of the calf and could have differed between treatment groups. Collection of colostrum samples immediately following birth and prior to suckling would be required to get a true indication of treatment differences in colostrum quality. Increasing the interval between calving and collection of first colostrum and an
increase in colostrum volume are associated with decreased IgG concentration of colostrum (Moore et al. 2005; Pritchett et al. 1991).

The original hypothesis of poorer quality colostrum from cows wintered on fodder beet was based on reports from farmers and veterinarians of cows not coming into milk well i.e. bagging up before calving. However, the lack of diet effect on Brix in the current experiment is consistent with results reported by Nowak et al. (2012) and Winkelman et al. (2008). Nowak et al. (2012) did however observe that calves from cows offered a high energy diet during the dry period had a better immunity status during their first weeks of life and increased daily body weight gain in the first three weeks of life.

Conclusions

High variation in Brix% between quarters within cows and between cows resulted in no statistically significant differences between treatments in colostrum quality. Additional measurements that would have strengthened the design of the current study include milk volume from the first milking and the IgG status of the calves on arrival to the calf shed. Additional research is required to understand the relationship between colostrum IgG concentration and volume and to determine if crop type affects the immunity status of the calves in the first week of life.

Acknowledgements

This work was conducted on behalf of New Zealand Dairy Farmers through funding from DairyNZ Inc. The authors acknowledge Jason Phillips and the farm team at the Southern Dairy Hub for management of the animals during the study, and Barbara Kuhn-Sherlock for the statistical analysis of the results.

References


Modelling nitrogen fertiliser by irrigation interaction for southern Australian dairy farms
Karen Christie*, Richard Rawnsleya and Richard Eckardb

aTasmanian Institute of Agriculture, University of Tasmania, Private Bag 3523, Burnie, Australia
bFaculty of Veterinary and Agricultural Science, University of Melbourne, Parkville, Australia

*Corresponding author. Email: Karen.Christie@utas.edu.au

Short title: N-Fertiliser irrigation interaction

Abstract

Using the biophysical whole farm systems model DairyMod, we examined the effect of four N fertiliser regimes, combined with four irrigation regimes, on pasture production and N loss via leaching at Mt Gambier, South Australia. The N fertiliser regimes represented varying levels of decision sophistication while the irrigation regimes represented ranges of accuracy in scheduling water application in response to rainfall deficit. Improving the level of sophistication in N fertiliser decision making, from a flat rate (i.e. 40 kg N/ha after each grazing event) to applying in response to plant demand, resulted in an 8% decline in annual dry matter (DM) production, while leached N losses were reduced by 46%. Relative to over-watering, irrigating to match rainfall deficit reduced N loss by 44% with no effect on DM production. Matching N fertiliser and irrigation inputs, to optimise pasture production, is critical to reducing N leaching and environmental impacts.

Keywords

DairyMod; pasture production; leaching

Introduction

Efficient use of key inputs such as N fertiliser and irrigation are important in maintaining the competitive advantage of pasture-based dairy production systems. The proportion of Australian dairy farmers using N fertiliser has increased from 28% in the early 1990’s to more than 70% on the early 2010’s (Stott & Gourley 2016). During this time, the intensity of use has also increased with typical average annual applications of approximately 200 kg N/ha.annum (Gourley et al. 2012). It is increasingly recognised that there is a need to move away from a blunt ‘rules of thumb’ for determining N application rates, towards a fertiliser decision based on better matching seasonal plant N demand. The dairy industry is the second highest user of agricultural irrigation water in Australia, at around 16% of total annual irrigation water use (ABS 2017). Farmers have frequently applied irrigation water at rates greater than plant water requirements, resulting in high losses of water and nutrients through drainage and/or runoff (Rawnsley et al. 2009). Whilst there is much past and present research exploring enabling practices and new technologies to improve N and water use efficiency, their interacting influences at the whole farm level must not be ignored. Modelling provides an efficient and effective means for exploring such interactions. This study explored the interaction of four N fertiliser and four irrigation regimes (16 in total) on pasture production and N leaching to ascertain the value proposition of scheduling N fertiliser and irrigation water inputs to match plant and rainfall-deficit demand on annual pasture production and leached N losses.
Materials and methods

The biophysical model DairyMod (Johnson 2016; version 5.7.5) was used to simulate a single paddock grazing experiment at one in southern Australia (Mt Gambier, South Australia) over 18 years (1999 to 2016). Cows were simulated to graze a perennial ryegrass pasture on the last day of each month to a residual biomass of 1.2 t DM/ha. Stocking rate was set such that all biomass above residual height was removed at each grazing event with no additional supplementary feed available to the grazing animal.

Four N fertiliser rates and four irrigation rates were examined in a 4 x 4 factorial design. The N fertiliser regimes were (i) 0 kg N/ha.month (ZR₀), (ii) 40 kg N/ha.month (FR), (iii) seasonally modified (SM; based on achieving 90% of maximum pasture production, equating to 426 kg N/ha.annum (Christie et al., 2018)), and (iv) precision plant (PP; apply 30 kg N/ha when live leaf N concentration dropped below 90% of optimum). Nitrogen fertiliser was applied either post-grazing (regimes 1-3) or in response to plant demand (regime 4).

Irrigation was applied in response to rainfall deficit, between 15th Sep and 15th Apr. The same initial soil water, carbon and N status was reset each year on the 1st Aug, thus each year was considered independently. The trigger to irrigate was based on when rainfall deficit (cumulative PET – rainfall) equalled 25mm. At this trigger, irrigation rates of 0 (rainfed; ZR₀), 10 (under watering; UW), 25 (Optimal; OP) and 40mm (overwatering; OW) were applied. The 18-year mean DM production (t DM/ha.annum) and leached N (kg N/ha.annum) was calculated for each N fertiliser by irrigation regime.

Results and Discussion

The average N fertiliser rate with the PP treatment was 128, 293, 283 and 212 kg N/ha.annum with the ZR₀, OP, OW and UW regimes, respectively (Fig. 1). Mean irrigation rates were 231, 576 and 940 mm/ha.annum for the UW, OP and OW regimes, respectively (Fig. 1). Across the 16 regimes, the estimated mean DM production varied between 7.0 and 18.0 t DM/ha.annum (Fig. 1, left hand graph) while leached N varied between 1 and 69 kg N/ha.annum (Fig. 1, right hand graph).
Relative to applying N fertiliser based on plant demand (PP), applying the FR and SM fertiliser regimes, averaged across the four irrigation regimes, resulted in 8 and 7% additional DM, respectively. However, this small increase in DM resulted in an 86 and 55% increase in leached N losses with the FR and SM regimes, respectively, driven by the substantially higher N fertiliser rates with the FR and SM regimes compared with the PP regime. There was no difference in DM production between OP and OW, at 15.7 t DM/ha.annum, when averaged across the four N fertiliser regimes, due to essentially no difference (~ 2 kg N/ha.annum) in N fertiliser inputs. However, matching irrigation to rainfall deficit (OP) reduced N leaching losses by 44%, relative to OW. In addition, the savings in water through better scheduling was substantive.

The PP/OP regime, as a representation of best management practice, resulted in an estimated mean pasture production of 16.6 t DM/ha.annum with 24 kg leached N/ha.annum (red dots in Fig. 1). Applying excess N fertiliser and irrigation (FR/OW), as a representation of potential current practice due to little incorporation of sophisticated decision-making, increased DM production to 17.9 t DM/ha.annum. This 8% increase in pasture production was achieved with an additional 187 kg N/ha.annum and 346 mm/ha.annum, relative to the PP/OP regime. However, leached N losses increased three-fold from 23 to 69 kg N/ha.annum, respectively.

Conclusion

This study has examined the potential environmental benefits of better matching N fertiliser and irrigation inputs on DM production and leached N losses. Sophisticated decision-making, with respect to N fertiliser and irrigation water applications, has been shown to dramatically reduce environmental N loss through leaching with small reductions in pasture production.

Acknowledgements

The ‘More Profit from Nitrogen: enhancing the nutrient use efficiency of intensive cropping and pasture systems’ project was supported by funding from Dairy Australia and the Australian Government Department of Water and Water Resources as part of its Rural R&D for Profit program.

References

ABS 2017. Water Accounts Australia 2015-16, category number 4610.0


Fig 1. Estimated mean annual pasture production (left) and leached nitrogen (right) at Mt Gambier across a range of nitrogen fertiliser and irrigation regimes. Red dots illustrate the pasture production and leached nitrogen with the precision plant/ optimal irrigation (PP/OP) regime while the black dots represent all other regimes.

Hydroxy-selenomethionine is an effective selenium source for pregnant heifers

D. T. Juniper\textsuperscript{A}, C. Rymer\textsuperscript{A}, M. Briens\textsuperscript{B}, M. De Marco\textsuperscript{B} and Y. G. Liu\textsuperscript{C}\textsuperscript{*}

\textsuperscript{A} School of Agriculture, Policy and Development, University of Reading, Reading, RG6 6AR, UK.
\textsuperscript{B} Adisseo France S.A.S., 10, Place du Général de Gaulle, 92160 Antony, France.
\textsuperscript{C} Adisseo Asia Pacific Pte Ltd, Singapore 179360

*Corresponding Author e-mail: Kevin.Liu@adisseo.com

Short title: Effect of hydroxy-selenomethionine in heifers

Abstract

This study aimed at evaluating hydroxy-selenomethionine (SO) efficacy compared with selenite (SS) for pregnant heifers. A total of 42 in-calf heifers were randomly assigned to 3 experimental diets: a non-Se-fortified basal diet (NC) or NC + 0.3 mg Se/kg DM as SS or NC + 0.3 mg Se/kg DM as SO. The study comprised of a seven-week washout phase followed by an eight-week supplemental phase. Blood samples were taken from each animal (n=14) at the enrolment, the end of the wash-out phase, 2-weeks pre-calving and immediately after calving. Blood samples were also taken from new-born calves. The results showed that dietary supplementation with Se to the heifers significantly increased Se level in plasma. At two weeks pre-calving, plasma Se concentrations (µg/ml) were 45.3, 61.7 and 69.9, respectively for NC, SS and SO treatments (P<0.001). After calving, Se concentrations in colostrum were 53.1, 73.0 and 92.4 (P<0.001), in calf plasma 31.2, 39.2 and 44.8 (P<0.001) respectively for NC, SS and SO. It is concluded that dietary Se supplementation can enhance Se status of the dam and their calves, and that SO is significantly more bio-efficacious than SS.

Additional keywords

inorganic/organic selenium, selenium pool, selenoproteins

Introduction

Selenium (Se) is an essential trace element in livestock for antioxidant, immune and reproductive functions. The principle mechanisms of Se are mediated by two Se containing amino acids, namely selenomethionine (SeMet) and selenocysteine (SeCys). SeCys residues constitute the primary structure of the functional selenoproteins (Labunskyy et al. 2014). Selenium deficiency can impair reproduction, development and production of dairy cows due to uncontrolled oxidative stress (Sordillo, 2013). There is a positive correlation between the Se status of the dam at parturition and that of her offspring, and it has also been shown that the Se status of calves born from dams fed on
diets supplemented with Se during late gestation is better maintained in the early post-partum period than that of calves receiving injectable sources of Se (Kincaid and Hodgson, 1989). Therefore, dietary Se supplementation is widely practiced, using either an inorganic form of Se such as sodium selenite (SS) or as organic forms such as Se-yeasts. Guyot et al. (2007) reported that the use of organic forms of Se during the late gestation further improves Se status of the offspring of Belgian Blue cows when compared to those receiving mineral Se. Recently a new molecule, hydroxy-selenomethionine (SO) has been introduced as a pure form of organic Se supplement. The present study aimed at comparing its efficacy with that of SS when offered to heifers during late gestation.

Materials and methods

A total of 42 in-calf Holstein Friesian heifers (566.8 ± 4.65kg; 170 days of gestation) were blocked by weight and calving date and then randomly allocated to one of three dietary treatments: a non-Se-fortified diet (0.029 mg Se/kg DM; NC) or NC + 0.3 mg Se/kg DM as SS or NC + 0.3 mg Se/kg DM as SO. Each treatment comprised of 14 animals. Each cow had an electronic ear tag that gave her access to a single Calan gate for individual feed intake recording. The study comprised of a seven-week washout period followed by an eight-week supplementing period. During the washout period the NC was offered to all animals at a rate of 25g DM/kg bodyweight day⁻¹. During the supplementing period animals received one of the three experimental diets.

Blood samples were taken from each heifer at enrolment, at the end of the wash out period, two weeks pre-calving and within 24 hours post-calving. Blood samples were taken from each individual calf as early as possible after parturition. Plasma were separated by centrifugation. Plasma samples were stored at −20°C for the subsequent determination of plasma total Se. A colostrum sample was taken as close to parturition as possible and stored at −20°C for the subsequent determination of colostrum total Se. Total Se in feeding stuffs, plasma and colostrum samples was determined by ICP-MS according to the method of Vacchina and Dumont (2018).

Data pertaining to heifer plasma Se were analyzed using the Mixed Model Procedure in the SAS vs. 9.4 software package (SAS Institute Inc. Cary, NC, USA). Factors in the model included treatment (2 df), time point (2 df) and expected calving date was used as a covariate term. Data pertaining to Se content in colostrum and to calf plasma Se were analyzed by one-way ANOVA. Treatment means were separated using the Tukey simultaneous pairwise comparison test. Statistical significance was set at P < 0.05.

Results and discussion

The results are reported in Table 1. The Se supplementation of heifers’ diets markedly increased plasma Se for both SS and SO heifers compared to NC. Heifers receiving SO showed a greater plasma Se level than SS (P < 0.001), which is attributable to the better bioavailability and non-specific incorporation of dietary SeMet into the protein pool derived from organic Se sources, as reported previously (Juniper et al. 2008; Phipps et al. 2008).
Plasma Se content of calves born from NC heifers was lower than that of calves born from heifers receiving Se supplements (P < 0.001; +25% with SS and +44% with SO), and greater in calves from SO heifers comparing to those fed on SS (P < 0.001; +14%). This enhanced Se status of calves born from dams receiving organic Se during late gestation was reported previously (Guyot et al. 2007) and is attributable to more efficient transfer of SeMet from the dam to the calf through the placenta. In fact, in this study the blood samples in calves have been taken as early as possible after parturition corroborating the hypothesis of SeMet transfer through placenta.

Comparing with SS, dietary supplementation with SO significantly enhanced Se concentrations in the plasma and the colostrum of heifers, and in the plasma of their calves (P < 0.001). Previous studies have shown that differences in milk Se responses between comparable doses of organic and inorganic Se supplements are a consequence of SeMet incorporation (Calamari et al. 2010), following the same mechanism as monogastric species as shown by Briens et al. (2013) and Jlali et al. (2014).

Conclusion
This study demonstrates that the Se status of dams and their calves was significantly improved by dietary supplementation with SO for the dams in comparison with mineral form SS, showing superior bio-efficacy of this organic Se molecule to inorganic Se.

References


**Table 1.** Effect of selenium source on plasma and Colostrum Se in pregnant heifers and on plasma selenium of calves

<table>
<thead>
<tr>
<th>Treatment</th>
<th>NC</th>
<th>SS</th>
<th>SO</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plasma Se (µg/ml)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enrolment</td>
<td>61.6</td>
<td>61.2</td>
<td>64.3</td>
<td>1.78</td>
<td>0.576</td>
</tr>
<tr>
<td>End of wash out period</td>
<td>50.2</td>
<td>52.4</td>
<td>54.9</td>
<td>1.78</td>
<td>0.896</td>
</tr>
<tr>
<td>Two weeks pre-calving</td>
<td>45.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>61.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>69.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.23</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Calving</td>
<td>38.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>58.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>67.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.78</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Colostrum Se (µg/ml)</td>
<td>53.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>73.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>92.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.58</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td><strong>Calf Plasma Se (µg/ml)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>31.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>39.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>44.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.45</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

NC = non-Se-fortified diet; SS = sodium selenite diet; SO = hydroxy-selenomethionine diet
Regional variation in the nutritive characteristics of perennial ryegrass in the three dairying regions of Victoria

ML Douglas\textsuperscript{a}, MJ Auldist\textsuperscript{a}, JL Jacobs\textsuperscript{a}, KB Kelly\textsuperscript{b}, AR Lawson\textsuperscript{b}, CM Leddin\textsuperscript{c}, SC Garcia\textsuperscript{d} and WJ Wales\textsuperscript{a}

\textsuperscript{a}Agriculture Victoria Research, 1301 Hazeldean Road, Ellinbank, Victoria 3821, Australia  
\textsuperscript{b}Agriculture Victoria Research, 255 Ferguson Road, Tatura, Victoria 3616, Australia  
\textsuperscript{c}Agriculture Victoria Research, 703-709 Raglan Parade, Warrnambool, Victoria 3280, Australia  
\textsuperscript{d}Dairy Science Group, The University of Sydney, 41/45 Brownlow Hill Loop Road Camden, New South Wales 2570, Australia

*Corresponding Author. Email: meaghan.douglas@ecodev.vic.gov.au

Abstract

The feed supply of most dairy farms in south-eastern Australia is based on grazing perennial ryegrass (PRG) supplemented with cereal grain in the dairy. Perennial ryegrass has benefits such as a low cost of production and high productive potential. The nutritive characteristics of PRG require evaluation as nutrients from supplements should complement nutrients consumed from pasture to optimise milk production. There is a large body of research describing these nutritive characteristics, however limited research has examined regional variation. The objective of this research was to characterise the nutritive characteristics of PRG cultivars from Gippsland, northern Victoria and south-west Victoria during five growth periods. During early and late spring, cultivars harvested from northern Victoria had higher crude protein, while cultivars from south-west Victoria had higher neutral-detergent fibre concentration. During summer, cultivars harvested from Gippsland had a higher metabolisable energy. During autumn cultivars harvested from Gippsland had higher potassium concentration, and during winter cultivars harvested from Gippsland and northern Victoria had higher phosphorus concentration. This research has demonstrated that regional variation in PRG nutritive characteristics exists within growth periods which needs to be considered when formulating supplementary rations to optimise milk production.

Keywords

perennial ryegrass; regions

Introduction

The Australian dairy industry is characterised by pasture-based feeding systems. Grazed pasture does not provide sufficient nutrients to support high milk production and supplements are commonly provided to increase nutrient intake (Wales and Kolver 2017). To formulate supplementary grain rations that optimise milk production, it is necessary to understand the nutritive characteristics of pasture.

Previous research has investigated the nutritive characteristics of PRG from different regions and seasons (Jacobs et al. 1999; Stockdale et al. 2001). There is, however, limited research investigating the nutritive characteristics of PRG in regions of Victoria over multiple growth periods. Understanding this variation can help farmers formulate rations so the nutrient supply from supplements complements that from pasture.
The objective of this research was to characterise the nutritive characteristics of PRG during five growth periods in three regions of Victoria. We hypothesised that there would be no difference in nutritive characteristics between the regions during early spring, autumn and winter when the pasture was in the vegetative stage, but there would be differences during late spring and summer due to different climatic conditions experienced at these times and the pasture entering the reproductive stage.

Materials and Methods

Samples of the same 18 PRG cultivars were collected during five key growth periods: early and late spring, summer, autumn and winter in 2015 to 2017. Samples were collected once during each period, except in summer where samples were collected over two summers due to unusually dry seasonal conditions.

All samples were harvested from a single experimental plot in each region, located at a pasture trial site at Lardner in Gippsland; a dairy farm at Mooroopna in northern Victoria; and a dairy farm at Terang in south-west Victoria. Thus, the term region is used to distinguish where the samples were harvested from. The samples were harvested at the 2.5 to 3 leaf stage with the consequence that samples were harvested on different dates in the different regions. The pasture was cut to grazing height (4 to 5 cm above ground level) using electric shears, and 500 g of fresh PRG was collected. Samples were placed in a plastic bag, and then placed into a chilled cooler with ice packs before being stored in a -20°C freezer. After freezing, samples were freeze-dried to constant weight, and then ground through a 0.5 mm sieve using an MEP rotor mill (Retsch GmbH, Germany). Analysis of the samples was by wet chemistry at CVAS Laboratories (Hagerstown, MD, USA).

Data were analysed using GenStat 18 (2015). Differences between regions within each growth period were performed by F-tests in a mixed model with additive fixed effects for growth period and region within each growth period. The random effects were cultivar, region by cultivar, growth period by cultivar, and region by growth period by cultivar. The average value for all cultivars in each region and growth period combination has been reported here from the analysis of all raw data.

Results and Discussion

Metabolisable energy (ME) concentration varied between regions only during summer and autumn. The variation between regions was greater during summer than during autumn (range of 1.2 and 0.5 MJ/kgDM, respectively). During summer, ME was higher in Gippsland, while during autumn ME was higher in Gippsland and northern Victoria (P < 0.05; Table 1). This indicates that energy supplied from supplements would have to be greater at the same levels of pasture intake for dairy cows grazing in south-west Victoria compared with the other regions during these growth periods.

Concentrations of crude protein (CP) varied between regions in all growth periods, excluding summer, with values ranging from 11.9 %DM in Gippsland during late spring to 30.9 %DM in south-west Victoria during winter. Previous research in northern and south-west Victoria also reported the highest concentration of CP occurred during winter (Jacobs et al. 1999; Stockdale et al. 2001). In the current experiment, during early and late spring CP was higher in northern Victoria, while during autumn and winter, CP was higher in Gippsland and south-west Victoria, respectively (P < 0.001; Table 1).

The concentration of neutral-detergent fibre (NDF) did not differ between the regions during autumn or winter; was slightly lower in Gippsland and northern Victoria during early and late spring; and was markedly lower in Gippsland compared with the other regions during summer (46 vs 56 %DM; Table 1). As the nutritional value of pasture is higher when NDF content is lower (Mertens 2009), supplementary rations with a low NDF content should be considered during late spring and summer.
During each growth period, calcium (Ca) was higher in Gippsland (Table 1). While the Ca content differed markedly between regions, it was relatively constant between growth periods within a region. The content of phosphorus (P), potassium (K), sodium (Na) and chloride (Cl) varied over the growth periods in all regions, and would have been influenced by the application of nitrogen fertiliser (McKenzie and Jacobs 2002). Hence, the need for mineral supplementation is likely to be more specific to each farm than ME, CP or NDF concentration.

Our results showed that most nutritive characteristics varied between the regions during each growth period. There were differences during late spring and summer for most variables, however there were also differences when the pasture was in the vegetative state. This was most likely more related to the different climatic conditions experienced at the time of sampling, and access to irrigation water, than to differences between cultivars.

Overall, the results show that it would be of limited use to formulate an optimal ration to supplement pasture using the average values of PRG nutritive characteristics across Victoria; instead sampling and feed test analysis of PRG should be recommended to obtain farm-specific information to account for the different climatic conditions experienced and farm management practices. Although our research has characterised the average nutritive characteristics of PRG cultivars in each region in the years that the samples were collected, there is variation in seasonal conditions between years. Therefore, to optimise ration formulation at any one time, farmers should be encouraged to collect samples of their pasture to determine the nutritive characteristics in that growth period in that year. Other recommendations include determining the amount of pasture available for grazing, as the proportion of the diet that is grazed pasture will vary throughout the year, and perhaps undertaking a soil test to help decide whether mineral supplementation is required. There is a need to develop real time analysis options in the future, as technology is developed, to measure pasture nutritive characteristics to enable appropriate ration formulation using supplements.

Acknowledgements

We wish to thank the Agriculture Victoria technical staff at Ellinbank, Tatura and Warrnambool for collecting and processing these samples. This work was funded by the Victorian State Government and Dairy Australia.

References

GenStat 18 2005. VSN International Ltd. 5 The Waterhouse, Waterhouse Street, Hemel Hempstead, HP1 1ES, UK.


### Table 1

Comparison of the nutritive characteristics of perennial ryegrass harvested from Gippsland, northern (N) and south-west (SW) Victoria during early spring, late spring, summer, autumn and winter. Values for ME are MJ/kg DM, while all other values are %DM. Means within a column for each season with different subscripts differ significantly.

<table>
<thead>
<tr>
<th>Region</th>
<th>Growth period</th>
<th>ME</th>
<th>CP</th>
<th>NDF</th>
<th>Ca</th>
<th>P</th>
<th>K</th>
<th>Na</th>
<th>Cl</th>
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</thead>
<tbody>
<tr>
<td>Gippsland</td>
<td>Early spring</td>
<td>11.4</td>
<td>20.0</td>
<td>41.5</td>
<td>0.61</td>
<td>0.44</td>
<td>3.27</td>
<td>0.22</td>
<td>1.27</td>
</tr>
<tr>
<td>N Victoria</td>
<td></td>
<td>11.2</td>
<td>23.5</td>
<td>42.0</td>
<td>0.37</td>
<td>0.44</td>
<td>4.04</td>
<td>0.51</td>
<td>1.96</td>
</tr>
<tr>
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<td></td>
<td>11.1</td>
<td>18.3</td>
<td>44.3</td>
<td>0.45</td>
<td>0.39</td>
<td>3.34</td>
<td>0.48</td>
<td>1.95</td>
</tr>
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<td>Gippsland</td>
<td>Late spring</td>
<td>10.3</td>
<td>11.9</td>
<td>50.5</td>
<td>0.60</td>
<td>0.21</td>
<td>1.88</td>
<td>0.21</td>
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<tr>
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<td>10.5</td>
<td>18.4</td>
<td>50.3</td>
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<td>0.34</td>
<td>2.74</td>
<td>0.64</td>
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<td></td>
<td>10.4</td>
<td>12.8</td>
<td>53.4</td>
<td>0.38</td>
<td>0.19</td>
<td>1.46</td>
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<td>Summer</td>
<td>10.7</td>
<td>15.0</td>
<td>45.7</td>
<td>0.71</td>
<td>0.16</td>
<td>2.25</td>
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<tr>
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<td>0.30</td>
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<td>0.17</td>
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<td>4.08</td>
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<tr>
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<td>0.32</td>
<td>3.26</td>
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<td>11.7</td>
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<td>37.2</td>
<td>0.33</td>
<td>0.48</td>
<td>4.20</td>
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</tr>
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<td>s.e.d</td>
<td></td>
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<td>0.85</td>
<td>1.14</td>
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<td>0.150</td>
<td>0.044</td>
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**P-value**

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<th>Autumn</th>
<th>Winter</th>
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Effect of feeding winter crops, designed to mitigate N loss, to early lactation dairy cows


Faculty of Agriculture and Life Sciences, PO Box 85084, Lincoln University, Lincoln 7647, Christchurch

Abstract

Crops such as fodder beet and forage oats catch crop have been shown to reduce N losses from dairy winter systems. A supplementation study was conducted in October 2015 to determine the effect of extending the use of winter crops, designed to mitigate N losses, on milk yield in early lactation. Four groups of 12 Holstein Friesian x Jersey cows/group were allocated 18 kg DM/cow/day as pasture (CON) plus 3 kg DM/cow/day of either fodder beet (FB), oats forage (OF) or oat silage (OS). The results show supplementation had effect (P < 0.001) on dry matter (DM) intake and (P <0.001) ME intake. However, there was no effect of supplement on milk composition or milk yield (2.5±0.15 kg MS/cow/d) (P = 0.865). There was no benefit in extending the feeding of fodder beet or oats (forage or silage) beyond the feed deficit and N loss mitigation period.

Key words

   early lactation, forage crops, dairy cows, milk yield.

Introduction

To manage nutrient losses from dairy winter systems low N crops such as fodder beet are fed to late gestation dairy cows. To reduce N leaching from grazed crop areas, catch crops such as oats could be sown directly after fodder beet. In commercial practice, consideration should be given to management of winter forages and how they may be integrated within the farm system on an annual basis. For instance using fodder beet or oats as supplements during lactation may simplify the transition on and off winter feeds. Also, supplementation can increase and sustain milk production, but responses will depend on pasture quality and the type of supplement offered (Bryant & Trigg 1982; Holmes 1987; Woodward et al., 2002). Slow pasture growth rates in spring and autumn also mean that some form of supplement will be required to manage rotation length. Therefore, we conducted a preliminary, non-replicated study to compare the management and feeding of winter crops on milk production in early lactation. We hypothesized that in early lactation fodder beet would be more effective, compared with oats, at supporting high milk yield.

Materials and methods

A 21 d supplementation study commenced in October 2015 at the Lincoln University Research Dairy Farm, Canterbury, New Zealand. Supplement treatments were: No supplement (CON); Fodder beet (FB); Oats forage (OF) and Oats silage (OS). All groups were offered perennial ryegrass and white clover pasture at an allowance of 18 kg DM/cow/day above a post grazing residual of 3.5 cm and all supplements offered at 3 kg DM/cow/day.
Four groups of twelve Friesian × Jersey, multiparous cows per group were balanced for: age (5.5 ± 3 years), milk solids production (2.53 ± 0.5 kg MS/cow/day), days in milk (66 ± 2 days) and live weight (509 ± 14 kg LW). Cows in supplement groups were adapted to diets and offered supplement from 0900 to 1100 h daily before a new pasture allocation.

Oven-dried sub-samples of pasture and supplement were determined for nutritive content by NIRS. The metabolizable energy (ME) content was calculated using the modified ADF (MADF) equation where ME (MJ ME/kg DM) = 14.55 – 0.0155 * MADF (CSIRO, 2007). Apparent dry matter (DM) intake was determined from pre and post graze herbage mass of pasture and OF using compressed height and quadrat cuts. Offered and refused FB and OS were measured daily. Milk yield was measured twice daily at morning and afternoon milking and subsamples of milk were collected every three days for analysis of composition. Live weight was measured automatically at the beginning (initial) and end (final) of trial.

Milk production variables were averaged across sampling days and analysed using the general linear model procedure of Genstat (18th Edition; VSN international Ltd) using supplement regime as the fixed term and cow as the random term. All means were separated using Fishers protected LSD test at the 5% significance level.

Results

Pre graze pasture mass was similar (P = 0.58) for all treatments but supplementation increase (P <0.001) post grazing residuals.

Table 1. Composition of pasture, and supplements: fodder beet (FB), oat forage (OF) and oat silage (OS) offered to cows in early lactation

<table>
<thead>
<tr>
<th></th>
<th>Pasture</th>
<th>FB (Bulb)</th>
<th>OF</th>
<th>OS</th>
<th>SEM</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pasture pre- mass (kg DM/ha)</strong></td>
<td>3326</td>
<td>3180</td>
<td>3231</td>
<td>3156</td>
<td>236</td>
<td>0.58</td>
</tr>
<tr>
<td><strong>Pasture post- mass (kg DM/ha)</strong></td>
<td>1571&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1775&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1875&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1653&lt;sup&gt;c&lt;/sup&gt;</td>
<td>16.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Neutral detergent fibre (% of DM)</strong></td>
<td>401&lt;sup&gt;c&lt;/sup&gt;</td>
<td>122&lt;sup&gt;d&lt;/sup&gt;</td>
<td>462&lt;sup&gt;b&lt;/sup&gt;</td>
<td>582&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Acid detergent fibre (% of DM)</strong></td>
<td>233&lt;sup&gt;c&lt;/sup&gt;</td>
<td>66&lt;sup&gt;d&lt;/sup&gt;</td>
<td>262&lt;sup&gt;b&lt;/sup&gt;</td>
<td>328&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.25</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Crude protein (% of DM)</strong></td>
<td>228&lt;sup&gt;b&lt;/sup&gt;</td>
<td>98&lt;sup&gt;d&lt;/sup&gt;</td>
<td>264&lt;sup&gt;a&lt;/sup&gt;</td>
<td>129&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Water soluble carbohydrate (% of DM)</strong></td>
<td>240&lt;sup&gt;b&lt;/sup&gt;</td>
<td>595&lt;sup&gt;a&lt;/sup&gt;</td>
<td>213&lt;sup&gt;c&lt;/sup&gt;</td>
<td>112&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Metabolisable energy (MJ/ kg DM)</strong></td>
<td>11.0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>13.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.07</td>
<td>&lt;0.001</td>
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SEM is standard error of the mean. Means with different superscripts are significantly different, P<0.05
Fodder beet had lower levels of protein and fibre and high sugars while OF had the highest protein and OS had the highest fibre content.

Substitution rate (SR) were 0.85, 0.65 and 0.31 for FB, OF and OS respectively. OS treatment had higher (P < 0.001) DMI while CON had the lowest. Cows were at peak lactation producing high yield of 2.48 kg MS/cow/day. However there was no treatment effect on milk yield or composition (Table 2). Also live weight were similar between treatment groups.

Table 2. Apparent intake, milk yield and milk composition of cows grazing pasture only (CON) or offered fodder beet (FB), oat forage (OF) or oat silage (OS) in early lactation

<table>
<thead>
<tr>
<th>Items</th>
<th>CON</th>
<th>FB</th>
<th>OF</th>
<th>OS</th>
<th>SEM</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture intake (kg DM/cow/d)</td>
<td>17.3a</td>
<td>15.0a</td>
<td>14.0bc</td>
<td>16.4a</td>
<td>0.18</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Supplement intake (Kg DM/cow/d)</td>
<td>-</td>
<td>2.7b</td>
<td>5.1a</td>
<td>2.9b</td>
<td>0.10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total intake (Kg DM/cow/d)</td>
<td>17.3b</td>
<td>17.7b</td>
<td>19.1a</td>
<td>19.3a</td>
<td>0.18</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ME intake (MJ ME/cow/d)</td>
<td>224</td>
<td>223</td>
<td>232a</td>
<td>223</td>
<td>1.70</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Milk yield (litre/cow/d)</td>
<td>26.4</td>
<td>26.2</td>
<td>27.0</td>
<td>26.1</td>
<td>0.75</td>
<td>0.865</td>
</tr>
<tr>
<td>Milk fat (%)</td>
<td>5.58</td>
<td>5.81</td>
<td>5.91</td>
<td>5.69</td>
<td>0.25</td>
<td>0.579</td>
</tr>
<tr>
<td>Milk fat (g/cow/d)</td>
<td>1.48</td>
<td>1.52</td>
<td>1.57</td>
<td>1.48</td>
<td>0.78</td>
<td>0.551</td>
</tr>
<tr>
<td>Milk protein (%)</td>
<td>3.62</td>
<td>3.74</td>
<td>3.72</td>
<td>3.63</td>
<td>0.09</td>
<td>0.439</td>
</tr>
<tr>
<td>Milk protein (g/cow/d)</td>
<td>0.95</td>
<td>0.98</td>
<td>0.99</td>
<td>0.94</td>
<td>0.03</td>
<td>0.816</td>
</tr>
<tr>
<td>Milk solids (kg/cow/d)</td>
<td>2.43</td>
<td>2.50</td>
<td>2.56</td>
<td>2.42</td>
<td>0.09</td>
<td>0.436</td>
</tr>
<tr>
<td>Live weight change (kg)</td>
<td>4.8</td>
<td>3.6</td>
<td>-4.0</td>
<td>-1.7</td>
<td>12.2</td>
<td>0.526</td>
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</table>

SEM is standard error of the mean. Means with different superscripts are significantly different, P<0.05

Discussion

In early spring, pasture is typically leafy and contains high protein content, therefore supplementation with high ME fodder beet was anticipated to improve milk yield relative to the more fibrous oats. The results of this study showed that fodder beet was no more effective than oats, either ensiled or grazed in situ, for improving milk yield in early lactation. These results also support the findings of Fleming et al. (2018) who found no MS response to fodder beet supplementation. The reason for lack of milk response in both this study and that of Fleming et al. (2018) appear to be due to high pasture substitution rates. In the current study variation in substitution rate for each supplement resulted in very similar apparent ME intakes. The high pasture residuals of supplemented treatments reflected an opportunity for cows to select pasture diets higher in quality than that on offer (as quantified by random sampling), which likely contributed to the lack of milk response to lower quality supplements (Penno et al. 1996).

Both pasture only and FB supplementation had good feed conversion efficiency (140 g MS/kg DM apparently eaten) compared with oats (approx. 130 g MS/kg DM apparently eaten). However, supplementation reduced pasture utilization which may reduce feed quality in subsequent grazing cycles. These preliminary findings indicate that pasture is likely to be spared if farmers use winter crops in early lactation to aid transition. Given that oats silage was poorer quality than other
supplements, feeding low N, ensiled oats in autumn (during feed shortage and for N loss mitigation period) may offer a more practical solution for the use of this catch crop.

References


Pasture pest impact and control options used on dairy farms in south-eastern Australia

Stuart Kemp1, Paul Umina2, David Hume3, Alison Popay4 and Brendan Cullen5*

1PastureWise Pty Ltd, 1485 Bamganie Road, Cargerie, Victoria 3334, Australia.
2Cesar, 293 Royal Parade, Parkville, Victoria 3052, Australia.
3AgResearch, Grasslands Research Centre, PB 11008, Palmerston North 4442, New Zealand.
4AgResearch, Ruakura Agricultural Centre, PB 3123, Hamilton 3240, New Zealand.
5Faculty of Veterinary & Agricultural Sciences, The University of Melbourne, Victoria 3010, Australia.
* Corresponding author. Email: bcullen@unimelb.edu.au

Short title: Pasture pest impact on dairy farms

Abstract
To better understand the impact of pasture pests and their control measures used on dairy farms in south eastern Australia, a survey of 76 farmers was conducted between November 2016 and July 2017. The survey covered true insects as well as other pests such as mites, slugs, snails and millipedes. Seventy percent of the survey respondents were from the state of Victoria, 16% from Tasmania, with the remainder from New South Wales and South Australia. There were few significant regional differences in farmer responses regarding impacts and the use of control measures, so these are not presented. Overall, 42% of dairy farmers surveyed reported they had resown a pasture at least once in the last five years as a response to insect damage. Beetles, including cockchafers and wireworms, were identified as the most common pest causing damage leading to pasture resowing. During the last 5 years, approximately half of the survey respondents did not use insecticide sprays or seed treatments, while approximately one quarter of respondents used these products every year. Insecticides were most commonly used in autumn months to protect establishing pastures, and the main pests targeted at this time were mites, lucerne flea, beetles, caterpillars and grasshoppers. Endophyte-infected pasture cultivars were used by approximately half of the respondents in at least 1 of the last 5 years, and were used every year by 15% of respondents. These results, combined with field survey and expert elicitation workshop data, will contribute to an estimate of the impact of pasture pests on dairy farm businesses.

Introduction
There is a lack of information on the occurrence, density, and level of damage caused by most pasture insect pests in Australian dairy regions. The impact of a small number of insect pest species has been investigated in a limited number of regions, and in these cases a substantial economic impact has been found. For example, the redheaded pasture cockchafer (RHPC - Adoryphorus couloni) has been estimated to cost annually $100/ha for lamb producers and $500/ha for dairying in Victoria (Berg et al. 1993), while in Tasmania, Pauley and Miller (1993) estimated losses due to RHPC, Corbies (Oncopera intricata), Winter Corbies (Oncopera rufobrunnea) and blackheaded pasture cockchafers (Accrossidius tasmaniae) at over $1M per annum. The sowing of pasture species resistant to pasture pests is recommended, but in perennial ryegrass (Lolium perenne)-based pastures widely used in the dairy industry, the use of cultivars infected with a selected endophyte has also been recognized as a potential strategy for managing pasture pests.
(Popay and Gerard 2007). A survey of dairy farmers in south-eastern Australia was conducted to determine the frequency that pests cause sufficient damage to warrant resowing of pastures, what pests caused the damage, and the use of insecticides and endophyte by farmers to control pest problems.

**Materials and methods**

The survey was conducted between November 2016 and June 2017, targeting dairy farms in south eastern Australia. Farmers were invited to participate in the survey through industry newsletters and other publications. The survey was completed online by 40 farmers, with a further 36 surveys completed by telephone calling. Producer survey results were summarised by region using the farm’s postcode. The regions and number of respondents in parenthesis were: Gippsland (22), Western Victoria (21), Murray (10), Tasmania (12), New South Wales (6) and South Australia (5). Due to sample size limitations (76 respondents), regional differences were analysed using only three categories rather than the 5-6 categories in the original questions. For example, questions that asked respondents to nominate how many years out of the last 5 years they have used insecticide treatments (0-5 years) were grouped as ‘never’ (0 years), ‘sometimes’ 1-3 years, and ‘nearly all the time’ (4-5 years). Regional differences in the survey responses were statistically analysed using maximum likelihood ratio chi-square test for categorical variables but were found to be not significant and are not reported.

**Results and Discussion**

On average, the producers surveyed managed farms of 270 ha in size ranging from 53 to 900 ha. Perennial pastures were sown by >80% of respondents in all regions except NSW. Annual/short term pastures were most commonly sown in the Murray region of northern Victoria and in NSW.

Overall, 42% of survey respondents said they had resown a pasture due to insect damage. Of those producers resowing pastures, 45% had resown a pasture once in the last 5 years and a further 30% had resown a pasture twice in the last 5 years and one producer reported resowing pastures as a result of insect damage every year. The average area resown was 27 ha, varying from an average of 5 ha in Tasmania to 40 ha in the NSW and Murray regions. Beetles, including cockchafers and wireworms, were identified as the most common pest causing damage leading to resowing. The decline in sown pasture species leading to pasture resowing is generally considered to be a result of multiple interacting factors, including drought, soil constraints and grazing pressure (Chapman et al. 2011; Culvenor and Simpson 2014). This survey indicates that pasture pests also play an important role.

The use of insecticides on pastures and forage crops is shown in Fig. 1. In general, approximately half of respondents had not used insecticides over the last 5 years, another group used insecticides every year and a further group of producers occasionally used insecticides. Overall, insecticide was most commonly applied as treated seed (42 of 75 respondents to this question), followed by spraying the establishing pasture (<3 months old, 41 respondents), by spraying established pasture (38 respondents), spraying winter crop (30 respondents) and spraying summer crops (7 respondents). Insecticide use was generally highest in autumn months (April and May), reflecting the main uses as treated seed and spraying establishing pastures (Fig. 1).
Endophyte-infected pasture seed was used by approximately half of the respondents in at least 1 of the last 5 years and was used every year by 15% of respondents. Use of endophytes has been shown to effectively control pest populations (e.g. Popay and Hume 2011), so increasing use of endophytes may be warranted in south eastern Australia to reduce the relatively high rate of pasture resowing due to insect damage observed in this study.

Figure 1. Number of years in the last 5 that producers used insecticide treated seed or insecticide spray on established pasture, establishing pasture and winter or summer crop. Results are totals across all survey regions.

The survey also indicated pastures pests are often not controlled. Seventy percent of survey respondents reported that there are times when they observe insect pests but do not do anything to control the infestation. This suggests that producers are making tactical decisions whether to control the pests or not. Lucerne flea and mites were most commonly reported pasture pests that were observed but not treated, followed by caterpillars, beetles, grasshoppers, snails and slugs.

This survey is the first of its kind to focus on the damage caused by pasture pests in south eastern Australia, and the control options used by dairy farmers. These results will be combined with a field survey of pasture pests and expert elicitation, to describe the impact of pasture pests on dry matter production and provide an estimate of the economic impact of pasture pests on Australian dairy farm businesses.

Acknowledgements
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References


Relationships between nitrogen inputs, outputs in product, and surpluses in New Zealand dairy systems

D Chapman*,†, K Macdonald‡, C Glassey§, I Pinxterhuis**, P Edwards*, P Beukes‡

* DairyNZ Ltd., c/- PO Box 85066, Lincoln University, Lincoln, New Zealand 7647, ‡ DairyNZ Ltd., Private Bag 3221, Hamilton, New Zealand 3240

* Corresponding author. E-mail: david.chapman@dairynz.co.nz

Abstract
This paper introduces a framework for quantifying relationships between nitrogen (N) inputs (from fertiliser, imported feed and fixation), outputs in animal product, farm gate N surplus, and N use efficiency (NUE) in grazing dairy systems. Data from 380 New Zealand dairy farms categorised according to farm system type (1 to 5, representing increasing reliance on imported feed), plus a 3-year farm systems experiment comparing different N fertiliser and supplementary feed inputs, were plotted within this framework. Within each system type, as more inputs were used to increase animal production, the farm N surplus increased and NUE declined. This trend was also apparent across the treatments in the systems experiment. In general, systems reliant on moderate-to-high feed inputs resulted in more N in product and higher NUE than systems with low reliance on imported feed, but still led to high N surpluses and, therefore, high nitrate leaching risk. Systems converting total N inputs of 300 kg/ha (from all sources) to milk efficiently (NUE = 30% or higher) are well-positioned to maintain high milk production with a relatively low N surplus (~200 kg/ha) and, therefore, relatively low N leaching risk.

Key words: Dairy systems; nitrogen; nitrate leaching; milk production; environment

Introduction
Dairy farmers in many regions of New Zealand are now, or soon will be, required to reduce nitrate leaching to comply with environmental regulations. The more nitrogen (N) that is brought into the farm system, the lower the efficiency with which it is used for pasture and milk production. The fraction which is not used for production, defined as the whole farm N surplus (N inputs in N fertiliser, imported feed supplements, and biological fixation minus N in milk and liveweight of sale animals), will eventually move into the wider environment (Whitehead 1995). Thus, the annual farm N surplus is a good indicator of likely N losses to water and atmosphere (de Klein et al. 2017, Pinxterhuis et al. 2018).

The advent of environmental regulations means that dairy system requirements for N are now defined by two factors: production, and environment. Farmers have a production goal (explicit or implicit), while the public has an environmental goal of reducing the N load in freshwater (made explicit by regulation). Nitrogen in animal products (milk, meat) and N leaching into freshwater (ground or surface water bodies) are both outputs from farm systems and they are often in conflict with one another. To help resolve the conflict, it is important to quantify the relationships between the two key outputs.

The aim of this paper is to present a general analytical framework in which N in product is plotted against the farm N surplus (as a proxy for environmental losses), and from which the management requirements (chiefly total N inputs, and nitrogen use efficiency, NUE = N in product / N inputs) for
achieving high production with low N emissions can be identified. Data from commercial dairy farms, and from a dairy farm systems experiment, are plotted within the framework to illustrate some general principles.

**Methods**

The framework is shown in Figure 1, where the x- and y-axes encompass both NUE (the diagonal lines), and N inputs (the points along the diagonal lines – some of which are labelled with kg N/ha total N input from fertiliser, feed imports and N fixation).

Physical farm data were drawn from 380 farms in DairyBase for the 2014/15 production year. An OVERSEER® simulation was created for each farm to calculate the N surplus. The data were segmented by system type, defined by the proportion of total feed supplied to the herd that was imported (Hedley et al. 2006): system 1 (no imported feed; n=12 farms); system 2 (4-14% of total feed is imported; n=91), system 3 (10-20% total feed is imported; n=156), system 4 (20-30% of total feed is imported; n=92) and system 5 (30-40% of total feed is imported; n=29). The relationship between N surplus and N output was analysed, and the best fit polynomial curve plotted in Fig. 1.

In addition, data were collated for eight treatments compared in a three-year farm systems experiment in the Waikato as reported by Macdonald et al. (2017). Five of the treatments used no imported feed (one received no N fertiliser, two received 200 kg N/ha/y and two received 400 kg N/ha/y), while pasture feed supply in the other three was supplemented by maize grain and/or maize silage (all with 200 kg N fertiliser/ha per year).

**Results**

In the farm data set, between 37% and 56% of the variation in the relationship between N surplus and N output was explained by a second order polynomial for all farm systems 1 to 5 (Fig. 1). Nitrogen use efficiency declined as N output increased for all system types. For example, for system 3 farms, NUE declined from 40% at total N input of 90 kg N/ha (N in product = 35 kg/ha, N surplus = 55 kg/ha) to around 22% at total N input of 300 kg N/ha (N in product = ~ 75 kg/ha, N surplus = 225). The N surplus increased by 170 kg/ha across this range.

In the farm systems experiment, NUE also declined as N in product increased from the ‘control’ treatment (zero fertiliser N input and imported supplement; 50% NUE; Fig. 1). When no supplement was used, maximum N in product (around 90 kg/ha) was reached with 200 kg N fertiliser/ha/year (with an additional ~ 100 kg N/ha coming from biological fixation). These systems were markedly more productive and efficient than the system 1 commercial farms. The systems treatments using supplements (triangles in Fig. 1) were also more efficient at using N than the corresponding system 4 and 5 commercial farms, albeit still resulting in high N surpluses (210 – 350 kg/ha).
Figure 1. Relationships between N surplus and N output in product in grazed dairy systems. Diagonal lines join points of equal nitrogen use efficiency (NUE; 50%, 33% and 25% are shown for comparison). Solid symbols on these lines indicate total N input (kg N/ha per year). Solid lines are fitted curves for commercial farms operating according to the definitions of systems 1, 2, 3, 4 or 5 in the New Zealand dairy industry (after Hedley et al. 2006). Open symbols are means for each of three years for treatments in a farm system experiment: circles = no N fertiliser or imported supplement; diamonds = 200 kg N fertiliser/ha/y, no supplements (2 stocking rates); squares = 400 kg N fertiliser/ha/y, no supplements (2 stocking rates); triangles = 200 kg N fertiliser/ha/y with supplements (three different types) (Macdonald et al. 2017).

Discussion

Whole-farm N surplus is the key nitrogen productivity variable to focus on when adapting farm systems to reduce nitrate leaching (Pinxterhuis et al. 2018). A high NUE does not necessarily lead to a low N surplus and therefore low risk of N loss. Rather, NUE is an indicator of the potential for increasing the efficiency of N use through management, and this needs to occur in tandem with a reduction in N inputs to achieve financial and environmental sustainability. Simply reducing inputs without improving the efficiency of use of those inputs leads directly to lower milk production, as shown by tracing toward the origin on the NUE lines in Figure 1. A combination of lower inputs leading to a lower N surplus, and increased efficiency of use of imported N, is required.

The farm data set used here was characterised by large variation among farms (data not shown), as noted also by de Klein et al. (2017). Hence, there is considerable potential for most farms to reduce N surplus. Farm systems where N inputs total 300 kg/ha per year from all sources (not just fertiliser; biological N fixation can contribute substantial amounts of N, e.g. Ledgard et al. 1999) and converting N and feed inputs to milk efficiently (NUE = 33% or higher) are well-positioned to maintain high milk production with a relatively low N surplus (~ 200 kg/ha) and, therefore, relatively low N leaching risk. Such systems should also be highly profitable (Macdonald et al. 2017). Nitrate leaching mitigation options such as use of feed supplements with low N content will result in only small reductions in environmental N losses if the system continues to operate with a high N surplus.
References


Validation of a satellite pasture measurement system

Grant Anderson* and Lorna McNaughton
Livestock Improvement Corporation, Private Bag 3016, Hamilton, New Zealand
*Corresponding author. E-mail: grant.anderson@lic.co.nz

Abstract

Satellite imagery of twenty New Zealand dairy farms over the 2011-16 period was obtained, along with farmer-provided measurements of pasture biomass in each paddock during the same time period. Images were matched against corresponding farmer measurements. Normalised Difference Vegetation Indices were computed for the paddocks in the satellite images, and a linear model was fitted between these indices and the farmer-measured biomass for a farm with rigorous pasture measurement. Pasture predictions from the linear model were computed for the remaining farms in the dataset, and were found to have a standard deviation of error of 329 kg of dry matter per hectare, similar to that obtained from the rising plate meter.

Keywords
satellite, pasture, dry matter

Summary Text

To manage you need to measure, but many farmers do not measure their pasture, due to the inconvenience and substantial time requirements. This paper describes the validation of a model that computes pasture dry matter measurements from satellite imagery. Such a tool would enable farmers to make better pasture management decisions without investing time and effort into pasture measurement.

Introduction

Optimal pasture management on a dairy farm provides substantial value to the farmer (Neal et al. 2017). However, for a farmer to manage their pasture optimally, they must measure and record it regularly, and the majority of farmers do not. An LIC survey of 460 dairy farmers (unpublished) indicated that, while two thirds of farmers undertake some form of pasture measurement, only about half did so regularly, and only 36% of those recorded that information electronically. The time required for regular measurement is substantial, and increases proportionally to farm size. Satellite pasture measurement provides a way for farmers to obtain regular pasture measurements with no labour input.

Satellite pasture measurement requires an algorithm to convert imagery into dry matter measurements (Clark et al., 2006; Mata et al. 2010). Vegetation indices are a family of algorithms that measure vegetation in satellite images. The Normalised Difference Vegetation Index (NDVI, Ali et al. 2016) estimates photosynthetic activity by measuring the difference in an area between the absorption of light in the photosynthetically active region (PAR) of the spectrum, and the absorption of light in the near-infrared spectral region. Live green plants absorb solar radiation in the PAR, and
reflect near-infrared light. After computing the NDVI for our data, we investigated the relationship between NDVI and dry matter measured by farmers.

The aim of this investigation was to identify a model to use for estimating dry matter in pasture from satellite imagery at paddock level.

**Materials and Methods**

To produce and validate our algorithm, we used pasture biomass (kilograms of dry matter per hectare, henceforth kg DM/ha) from a farm (henceforth the ground truth farm) with weekly farm walks by experienced plate meter operators, and satellite imagery for that farm. We used similar data from 19 other farms to evaluate the algorithm.

To minimise confounding variables such as terrain and available water, the farms were selected from the Canterbury region of New Zealand. This region is largely flat, and the selected farmers in this region utilised irrigation to ensure year-round availability of water.

Satellite data were obtained from our satellite image provider for the selected farms, for dates from January 2012 to May 2016. These data were mainly from the Sentinel and RapidEye constellations, and contained measurements in the red, green, blue and near-infrared (RGBN) spectral ranges for each paddock of each farm in the dataset. Farmer measurements (kg_DM/ha) were also obtained for the same time range from LIC’s Land and Feed database. Unfortunately, the Land and Feed system does not record the device used to obtain measurements. The two datasets were combined to produce a dataset that allowed us to use farmer measurements to evaluate satellite estimates.

Farmer measurements tended to be weekly at their most frequent, and satellite measurements were increasingly scarce for years prior to 2017. For example, one farm in our analysis was imaged three times in December 2014, seven times in December 2016, and 31 times in December 2017. Most farms are now imaged daily, though cloud still restricts the number of useful images. This meant that intersections between satellite and farmer measurements were rare; only 239 paddock measurements were available for the ground truth farm.

To increase the size of our ground truth dataset, we allowed a one day gap between measurements from the two systems, which produced a total of 623 records. We computed the NDVI for the mean of the spectral measurements for each paddock. We identified a large number of points where paired farmer dry matter measurements and NDVI results did not fit the relationship that most of these pairs exhibited. Inspection of the satellite imagery on and around the dates in question identified two main sources of this divergence. The first was the window of time between the satellite image capture and the farmer measurement; the paddock could be grazed during this period, creating a substantial mismatch between the two measurements. The second was cloud – when cloud in an image obscured the farm being measured, an accurate pasture measurement could not be derived. Sixty-eight paddock records were removed from the ground truth dataset, leaving 555 records for model construction.

A linear model was fitted to the paired dry matter and NDVI data from the ground truth farm in R (R Core Team, 2018) to predict dry matter from NDVI; the dry matter was the response variable, and NDVI the predictor.
Results

The standard error of the residuals for the linear model was 335 kgDM/ha.

The response of NDVI to increased dry matter began to diminish between 2,500 and 3,000 kgDM/ha. A literature review identified that such saturation was a property inherent to NDVI and one paper contained a correction (RVI) that could be applied to NDVI to mitigate this effect (Gu et al, 2013). When we applied this adjustment to our data and refitted the model, the standard error of the residuals for the RVI-based model was 326 kgDM/ha.

This model was then applied to a test set comprising the 19 remaining farms in the data. The standard deviation of error for the model predictions was 329 kgDM/ha. Figure 1 shows a comparison of farmer-measured biomass and the biomass predicted by the model.

Figure 2: Comparison of farmer-measured and satellite-predicted biomass. No outlier values have been removed.

Including the satellite measurements within one day of the plate meter measurements did not have a significant effect on the accuracy of the model on the test data (an F test comparing the standard deviations of error for exact-day and within-one-day models returned a p-value of 1, indicating those values were not significantly different).
Discussion

The observed standard deviation of error for satellite prediction compared well with that reported in the literature for the rising plate meter; for example, L’Huillier & Thomson (1988) report a standard deviation of error of 311-610 kg DM/ha for the rising plate meter, and King et al. (2010) report a rising plate meter RMS error ranging from 441 to 773 kg DM/ha across five regions of New Zealand, and also give a comparison to the CDAX Pasturemeter (RMS range 520 to 668 kg DM/ha). For our results above, the RMS error is very similar to the standard deviation of error (within one kg DM/ha), due to minimal bias. This provides an indication that satellite-based predictions of pasture dry matter could be used as a pasture measurement tool on-farm.

Mata et al. (2011) reported an overall RSE of 200 kg DM/ha for satellite estimation in their work in the Canterbury region; their algorithm utilised at least one spectral band unavailable to us, and also data external to the satellite image. This indicates that there could be room to improve our current system. Satellite estimation of pasture dry matter was offered as a commercial service in Australia until recently (http://www.pasturesfromspace.csiro.au/ )

In Figure 1, we have not removed any outliers from the test dataset, to give an indication of the distribution of these points. These outliers are clearly distinct from the main relationship between prediction and measurement. There are a number of factors that interfere with the relationship between plate meter measurement and satellite estimation (Mata, 2011). Cloud and grazing are the main sources of these deviations.

The saturation of the NDVI measurement, beginning in the 2,500-3,000 kgDM/ha range, could limit its effectiveness on farms that regularly run paddock covers over 3,000kgDM/ha.

With the increased quantity of satellites in orbit, it should be increasingly easy to match satellite measurements against each farmer measurement, and thus gather more comprehensive datasets to build new models or refine existing ones.

The availability of regular pasture measurement data, without an onerous time investment, would give farmers the capability to make informed feeding decisions for their herds, and thus improve the productivity of their farms.

Acknowledgements

We gratefully acknowledge the work done by Brooks Stephenson and the team at FarmShots, North Carolina, in producing the image processing architecture that allowed us to undertake this work. Our thanks also go to the rest of the SPACE team at LIC, whose work enabled this project.

References


Conflicts of Interest

Livestock Improvement Corporation is currently offering a satellite pasture measurement service (SPACE™) based in part on this work.
Estimating Pasture Biomass with Planet Labs CubeSats

M Asher¹, P Raedts², MT Harrison², J Hills² and RP Rawnsley²
¹4521 72nd St, Urbandale IA 50322, USA
²Tasmanian Institute of Agriculture, University of Tasmania, Tasmania, Australia.

Abstract

Dairy farms require efficient monitoring of pasture biomass. However, physical proxy or destructive measurements are time-consuming, subject to sampling and collection error, and cannot characterise spatial biomass within entire paddocks. Until recently, spatial resolution and temporal frequency of satellite data have been insufficient to achieve effective management. We developed a model for biomass prediction based on data from new Planet Labs satellites to evaluate its utility in the context of commercial dairy farming. While the model had minimal residual error on the farm with the highest quality data (RMSE 260 kg/ha), validation of the model on new farms was poor. Accurately estimating biomass for the calibration farm is promising, but further work is necessary to develop a model which extrapolates robustly.

Introduction

The profitability of New Zealand (NZ) and Australian dairy farms is closely related to the amount of pasture consumed (t DM/ha) (Chapman et al. 2008). To optimise pasture consumption, dairy farm managers require timely estimates of pasture biomass. Ground-based measurements are time consuming and subject to sampling errors. Utilising satellite imagery to estimate biomass is an actively researched alternative, including work focusing on pastures (Hill et al. 2004 and Mata et al. 2011). However, widespread adoption has been limited since no existing approaches provide regular, global estimates at a spatial resolution that is able to capture the variation between or within typical-sized dairy paddocks (2-10 ha). Approaches have been limited by the number of cloud-free images from available satellite data sources namely MODIS (250 m near daily from 2002), Landsat-8 (30 m every 16 days from 2013) and Sentinel-2 (10 m every 5 days from 2017). Aside from work to combine remote sensing data with biophysical simulation models (Hill et al. 2004), methods have also been limited to simple regression algorithms, despite the availability of more effective approaches such as gradient boosted trees and convolution neural networks. In 2017, Planet Labs launched a constellation of over 160 CubeSats (3000 cm³ each) which image the entire globe daily with 3 m resolution. This frequency and resolution appear promising with respect to pasture management. However, the CubeSat satellites are comparatively low cost with low radiometric quality and cross-sensor inconsistencies (Houborg and McCabe 2016), which may limit reliability for biomass estimation. The CubeSat bands include a wider range of frequencies than the corresponding bands on for example Sentinel 2, they overlap with one-another and vary between satellites. Here our aim was to assess the accuracy of the new Planet Labs dataset for the estimation of pasture biomass with sufficient reliability to be useful in operational decision-making of Australian dairy farms.
**Materials and Methods**

This study used high resolution satellite imagery from the PlanetScope constellation and moderate resolution imagery from MODIS to estimate paddock level biomass at four dairy farms in Northern Tasmania, Australia from June 2017 to May 2018. Every paddock had weekly biomass measurements. Three farms gathered data using rising-plate meters (RPM) and similarly trained operators (one operator per farm, formula 125x + 500), and one used a C-Dax sensor (farm D in Table 1, formula 17.5x + 850). For each paddock and date, we used MODIS NDVI (MOD13Q1.006), Planet (PSScene4Band Analytic Surface Reflectance) NDVI, red, blue, green, NIR, sun elevation, view angle, sun azimuth, and the ratios red:green, red:blue, NIR:green, NIR:blue and blue:green as features. We used a linear interpolation in time to compute the output of interest, biomass, at each of the dates for each paddock from the available weekly paddock level ground measurements. Outliers were removed using an elliptic envelope assuming a contamination of 0.1. A machine learning technique, XGBoost (Chen and Guestrin, 2016), was employed to predict biomass from the above features.

To assess the performance of the XGBoost model, we computed the cross-validation root mean square error (RMSE) (Table 1) on a holdout dataset of 90 days. A different model was trained for each farm. We also conducted a cross-validation using the same model for all farms and leaving one farm out at a time. Normalised RMSE was computed as the RMSE divided by the mean of the observed data. Mean bias was computed as the mean of the observed data less the mean of the predicted data.

**Results & Discussion**

To be useful to commercial dairy farming, pasture biomass predictions must be as precise as manual methods and be available daily. A farm specific model could be trained to provide paddock-level growth rates for a dairy farm. Grazing time was not explicitly accounted for in the model – pasture growth was modelled on satellite and biomass observations only. However, the calibrated model performed poorly on remaining farms resulting in overestimation at low biomass levels and significant underestimation of observed biomass at levels greater than ~2000 kg/ha (Maatanga and Skidmore, 2004). The poor model evaluation can be partially explained by:

- Planet Labs data has known radiometric quality and registration issues (Houborg and McCabe, 2016)
- The four farms taken together are a sparse dataset in the selected features. Tree based models have no mechanism for extrapolation.
- Pasture biomass exhibits significant intra-paddock variability. The selected model accounts for paddock averages only.

<table>
<thead>
<tr>
<th>Farm</th>
<th>RMSE1</th>
<th>RMSE2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>610</td>
<td>524</td>
</tr>
<tr>
<td>B</td>
<td>472</td>
<td>426</td>
</tr>
<tr>
<td>C</td>
<td>511</td>
<td>519</td>
</tr>
<tr>
<td>D</td>
<td>374</td>
<td>438</td>
</tr>
</tbody>
</table>

Table 1. XGBoost validation RMSE. RMSE1 = validation for one farm leaving 90 days out, RMSE2 = validation using all farms leaving one farm out
NDVI does not fully capture biomass trends. This may be explained in part by pasture’s tendency for darker colours with slower growth rates in winter along with lighter colors during times of faster growth.

The model performed significantly better on the farm with C-Dax data and more uniform perennial ryegrass pastures. The cause of this is unknown.

A number of avenues exist to improve the model:

- Create a higher quality time series of input imagery by synthesizing MODIS, Landsat, Sentinel and Planet imagery for example (Houborg and McCabe 2016).
- Include a land use classification feature in the model to filter out non-pasture pixels.
- Collect higher quality training data for additional farms and date ranges.
- Explore other modeling approaches, for example deep learning methods which incorporate the spatial aspect of the imagery rather than simple paddock averages.

In conclusion, our work with the machine learning technique and imagery from Planet Labs and MODIS indicates that precise estimates of pasture biomass (RMSE 265 kg DM/ha) are achievable. However, further work is required to diagnose the issues causing the poor skill of the model in predicting biomass on validation paddocks.

References


Cattle sensory perception of ergovaline during short-term exposure in perennial ryegrass

Short title: Cattle sensory perception of ergovaline

KN Tozer\textsuperscript{a}, GP Cosgrove\textsuperscript{b}, DE Hume\textsuperscript{b}, WJ Mace\textsuperscript{b}, RM Greenfield\textsuperscript{a} and CA Cameron\textsuperscript{a}

\textsuperscript{a}AgResearch, Ruakura Research Centre, Private Bag 3123 Hamilton, New Zealand

Corresponding author. E-mail: katherine.tozer@agresearch.co.nz

\textsuperscript{b}AgResearch, Grasslands Research Centre, Private Bag 11008, Palmerston North 4442, New Zealand

Abstract

The study aimed to determine to what extent dairy heifers could distinguish between perennial ryegrass mini-swards with and without ergovaline. Perennial ryegrass infected with AR5 (+ ergovaline) or AR1 (- ergovaline) was established as replicated mini-swards. Over seven feeding sessions, each of seven heifers was offered the test pair once. There was no effect of endophyte type on pre- and post-grazing sward surface height, the number of bites or bite rate (P>0.05). Heifers did not discriminate between perennial ryegrass mini-swards in this short-term mini-sward test. Longer-term tests may be required for deterrent effects to be detected.

Keywords

ergovaline; alkaloids, endophyte; preference; perennial ryegrass

Introduction

Wild-type endophyte (\textit{Epichloë festucae var. lolii}) induces toxic effects when ingested by livestock due to the effects of lolitrem B and ergovaline (Easton 1999). When a choice between endophyte-infected (E+) and endophyte-free (E-) ryegrass is available, animals avoid E+ pasture, although not totally (Cosgrove et al. 2002). This deterrence has often been attributed to a learned, post-ingestion feedback to alkaloids, but the role of sensory perception is unknown. If this role could be established and the causal compounds identified, it may be possible to use selected endophytes which deter overgrazing. Avoidance of overgrazing based on sensory perceptions would be preferable to learned avoidance based on toxic effects.

In comparing defoliation of E+ (wild-type) and E- swards of ryegrass, Edwards et al. (1993) demonstrated that sheep grazed at the same rate for several days, but eventually sheep offered E+ severely reduced their pasture consumption, which they attributed to reluctance to penetrate the pseudostem layer of E+ swards. As ergovaline is concentrated in the tiller base (Easton 1999) it may be a suitable candidate alkaloid for deterring overgrazing.

Our objective was to test if young cattle discriminate based on their initial perceptions between two ryegrass mini-swards, one with ergovaline-producing endophyte and the other ergovaline-free endophyte. The hypothesis was that young cattle can discriminate between mini-swards that differ in the presence of ergovaline.
Materials and methods

The perennial ryegrass experimental line GA66 infected with either AR1 (- ergovaline) or AR5 (+ ergovaline) endophytes provided a paired contrast to quantify the extent to which heifers discriminate.

Mini-sward establishment and management In late spring 2016 the two ryegrass lines were established from seed and planted in trays of 25 cm x 40 cm x 7 cm. The developing mini-swards were regularly fertilised, watered and trimmed over summer in preparation for use in early autumn 2017. To accustom heifers to the feeding procedures to be used during the test period, they were offered paired small trays containing silage, then meal, then endophyte-free ryegrass for short periods in the week preceding the test feeding. During this time heifers that were not adapting to the experimental conditions were removed from the trial group.

Presentation of mini-swards To determine if dairy heifers can discriminate between perennial ryegrass mini-swards that differ in the presence of ergovaline, a mini-sward pair was presented to each of seven heifers. In each presentation, the relative left or right position of each tray of the pair was randomised. Feeding sessions, each approximately 5 minutes, occurred between ca. 1000 h and 1230 h over seven days between 10 and 20 March 2017. Heifers were removed from old (>18 yrs) perennial ryegrass-based pasture 4 hours before each feeding session to ensure that they were hungry before grazing. The mini-sward pairs were presented in the same position in the pen for all feeding sessions. The heifer and the mini-swards were removed from the feeding pen once a heifer had finished grazing, which was defined as a 30 second interval without grazing after a bite was taken.

Measurements Mini-swards were sampled for ergovaline concentrations before each feeding session by removing 30 tillers at the plant base from each tray and combining them into one sample per tray. Samples were then analysed for ergovaline using reverse-phase chromatography (Moore et al. 2015). The height of 30 randomly selected tillers from each tray, from the extended leaf tip to the surface of the growing media, was measured to the nearest millimetre before and after grazing. Heifer feeding behaviour (including behaviour during presentation of the swards such as sniffing, sampling, and the time spent biting each of the choices) was captured by video-camera. Subsequently the tray first eaten from, the number of bites from each tray and the duration of biting from each was transcribed from each recording.

Statistical analyses The AR1 and AR5 mini-sward data were analysed as a paired t-test in Genstat 18th edition (VSN International Ltd. 2015).

Results

The concentration of ergovaline averaged 1.5 mg/kg DM in AR5-infected mini-swards and was not present in AR1-infected mini-swards. There was no effect of endophyte contrast on pre-grazing mini-sward height, post-grazing mini-sward height, or changes in height during grazing (Table 1, P>0.05). There was no effect of endophyte contrasts based on grazing behaviour captured on video camera, including the total number of bites, biting rate, overall preference (percentage of total
grazing time spent grazing each of the two treatments), and preference in the first few minutes (Table 1, P>0.05). Results show an apparent lack of detection of ergovaline.

Table 1. The effect of ergovaline presence (ERG+) or absence (ERG-) on sward height, defoliation characteristics and preference by heifers offered mini-swards for short grazing durations.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>ERG+</th>
<th>ERG-</th>
<th>SED</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-sward height pre-grazing (mm)</td>
<td>170.9</td>
<td>164.6</td>
<td>7.05</td>
<td>0.256</td>
</tr>
<tr>
<td>Mini-sward height post-grazing (mm)</td>
<td>68.1</td>
<td>58.1</td>
<td>6.34</td>
<td>0.067</td>
</tr>
<tr>
<td>Change in height during grazing (mm)</td>
<td>102.8</td>
<td>106.5</td>
<td>10.68</td>
<td>0.639</td>
</tr>
<tr>
<td>Total number of bites</td>
<td>45.3</td>
<td>49.9</td>
<td>8.58</td>
<td>0.480</td>
</tr>
<tr>
<td>Biting rate (per minute)</td>
<td>29.7</td>
<td>28.0</td>
<td>2.46</td>
<td>0.358</td>
</tr>
<tr>
<td>Overall preference (%)</td>
<td>46.3</td>
<td>53.7</td>
<td>4.38</td>
<td>0.400</td>
</tr>
<tr>
<td>Preference in the first few minutes (%)</td>
<td>47.7</td>
<td>52.3</td>
<td>33.58</td>
<td>0.850</td>
</tr>
</tbody>
</table>

Discussion

Contrary to our hypothesis, the results suggest that dairy heifers did not discriminate between the two perennial ryegrass-endophyte combinations that differed in the presence or absence of ergovaline. Our expectation, based on previous studies using wild-type endophyte, was that of the 3 main alkaloids ergovaline, peramine and lolitrem B, ergovaline was the most likely single alkaloid that could be used to deter grazing. It is concentrated in the base of tillers where deterring animals from grazing would be most beneficial for preventing the effects of overgrazing on pasture persistence (Nicol and Klotz 2016).

The reasons why cattle did not discriminate on the basis of ergovaline is not clear. This result differs from a previous study where sheep given a choice partially rejected E+ (containing all three alkaloids) in favour of E- but when there was no choice, E+ or E- were equally acceptable (Cosgrove et al. 2002). The concentrations of ergovaline in our study were greater than those normally seen in wild-type infected pastures at the same time of year. The deliberately short-term exposure only allowed cattle to detect odour (taste is unlikely because ergovaline is concentrated in the lower portion of tillers). It is possible that there are not sufficiently strong volatiles associated with ergovaline to be sensed by cattle when taking bites from the upper, leafy strata of the sward. It may require grazing of the pseudostem. This contention is supported by the study of Edwards et al. (1993) who showed that the reluctance to graze into the pseudostem horizon of E+ swards, occurred only after sheep had removed the leaf layer after several days of grazing. Cattle may be less able
than sheep to detect ergovaline. Further research with shorter swards and a longer exposure duration than used here, is needed to confirm this.

REFERENCES


Identifying Research Priorities for Establishing Plantain On-farm

J. P. Edwards and J. B. Pinxterhuis

DairyNZ, PO Box 85066, Lincoln University, Lincoln 7647, New Zealand.

Abstract
A simple model was developed to test the cost sensitivity of seven factors in achieving a target percentage of 20, 25, or 30% plantain across a farm. Of the seven factors, the most important were the percentage of plantain that can be established in an existing sward and the cost of doing so (e.g. broadcast, drill). The percentage of plantain establishing in new pastures and the persistency of plantain were also important factors. The cost of plantain seed and sowing rate into existing pastures were less important in determining the overall establishment cost. The rate of pasture renewal had little effect on cost. Introducing and maintaining 20% to 30% plantain in pasture across the whole farm would cost $20/ha to $250/ha, with the cost of achieving 30% plantain being 1.5 to 2 times more expensive than 20%. Results indicate there is a strong incentive for research to identify methods that can achieve at least 20% plantain establishing into existing pastures, irrespective of the target plantain content.

Introduction
Plantain can reduce nitrogen (N) leaching via reduced rate of ammonia release in the rumen (Navarrete et al., 2016) and N concentration of urine (Box et al., 2017), improved cool-season growth and N uptake (Martin et al., 2017) and inhibited nitrification in the soil (Carlton et al., 2018).

To translate these experimental results into improved environmental outcomes they must be scaled up to farm level. Research to-date would indicate the amount of plantain required may be in the order of 20-30% of the total diet to significantly reduce urinary N concentration (FRNL, unpublished results), and to make full use of its effects on soil N, it likely needs to be evenly dispersed in pasture across the farm. At farm scale, it is not yet clear how a target amount of plantain could be achieved.

The objective of this study was to identify which factors have the greatest influence on the cost of achieving a target plantain population, identifying them as priorities for future research. We hypothesised that the percentage of plantain able to be established into existing swards would have a large impact on the amount of plantain on the whole farm and the overall cost.

Materials and Methods
Model development
A model was developed using Microsoft Excel 2016 to estimate the cost of achieving an average of 20%, 25% and 30% of plantain in pasture dry matter across the whole farm. It was assumed there were no other costs or benefits associated with establishing plantain, such as changes in annual or seasonal dry matter supply or pasture quality. Therefore, situations that minimise the costs may not be the most profitable at farm scale. Inputs for the model, and outputs calculated for a steady-state situation, are presented in Table 8. A table was established with three columns, the first consisted of the labels \( n = 0 \) to \( T \); \( T \) was the number of years it takes to renew all pasture on the farm. The second column contained a binary score \( B \), with \( B = 1 \) if the calculated plantain content of pasture of \( n \) years old (PropP\(_n\)) had dropped below the trigger for plantain re-establishment in existing pasture (%PTrig). The third column then calculated PropP\(_n\) + \( B \times \%\)PReEst (defined in Table 8).
The Solver add-in of Microsoft Excel 2016 was used to determine %PTrig, minimising cost, required to reach each of the three targets for plantain content on the farm.

**Table 8. Inputs and calculated outputs for the model to estimate the proportion of plantain on farm and cost of achieving it.**

<table>
<thead>
<tr>
<th>Physical inputs</th>
<th>Code</th>
<th>Defaults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm size (ha)</td>
<td>A</td>
<td>375 ha</td>
</tr>
<tr>
<td>Annual pasture renewal rate (% of farm)</td>
<td>%Renew</td>
<td>10%</td>
</tr>
<tr>
<td>Plantain establishing in new pasture (% of pasture dry matter)</td>
<td>PropP₀</td>
<td>50%</td>
</tr>
<tr>
<td>Plantain re-establishing in existing pastures (% of pasture dry matter)</td>
<td>%PReEst</td>
<td>12%</td>
</tr>
<tr>
<td>Annual plantain survival (% remaining)</td>
<td>%PSurv</td>
<td>60%</td>
</tr>
<tr>
<td>Threshold of plantain % triggering re-establishment (% of pasture dry matter)</td>
<td>%PTrig</td>
<td>#</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Economic inputs</th>
<th>Code</th>
<th>Defaults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantain sowing rate in new pasture (kg seed/ha)</td>
<td>PSowR</td>
<td>1 kg/ha</td>
</tr>
<tr>
<td>Plantain sowing rate for re-establishment (kg seed/ha)</td>
<td>PReEstR</td>
<td>4 kg/ha</td>
</tr>
<tr>
<td>Plantain seed cost ($/kg)</td>
<td>PSeedC</td>
<td>$15/kg</td>
</tr>
<tr>
<td>Cost to re-establish the plantain in existing pasture ($/ha)</td>
<td>ReEstC</td>
<td>$120/ha</td>
</tr>
<tr>
<td>Cost of pasture renewal ($/ha)</td>
<td>RenewC</td>
<td>$500/ha</td>
</tr>
</tbody>
</table>

| Calculated outputs | | |
|---------------------|-------------------|
| Annual area of pasture renewal (ha) (A x %Renew) | ARenew | - |
| Time to reach steady state (years) (100 / %Renew) | T | - |
| Percent of plantain on pastures of n years old (PropPₙ x %PSurv) | PropPₙ | |
| Area needing plantain re-established in steady state (ha) | (Σₙ₌₀(PTrigₙ) x ARenew) | ARenEst | - |
| Percent of farm needing re-establishment in steady state (%) (ARenEst / A) | %ReEst | - |
| Percent of plantain on farm (% of pasture dry matter) (mean of PropPₙ(0-7)) | %PFarm | - |
| Cost of achieving target plantain for farm ($) | TCost | - |
| Cost of achieving target plantain ($/farm ha) (TCost / A) | HaCost | - |

* Dependent on target; scenarios used were an average of at least 20, 25, and 30% plantain of pasture dry matter across the whole farm

* Only used in the scenario comparing sensitivity to annual pasture renewal rate

* Cost above ‘current’ farm practice; cost of pasture renewal only included when comparing sensitivity to pasture renewal rate.

**Scenarios**

Seven scenarios were tested, in each scenario only the variable of interest was changed, assumptions for other variables (defaults) are presented in Table 8. The first scenario tested the effect of the annual rate of pasture renewal. For this scenario, it was assumed that there was no pasture renewal conducted as part of standard farm practice. In the remaining scenarios the cost of pasture renewal (RenewC) was assumed to be part of standard farm costs.

The second scenario tested the effect of different responses to sowing 1 kg/ha of plantain seed in the new pasture seed mix. The third scenario tested the effect of different responses to sowing
4 kg/ha of plantain seed into existing pastures. The fourth scenario tested the effect of different rates of plantain survival from one season to the next (100% + natural reseeding – death). The fifth, sixth and seventh scenarios tested the effect of the cost of plantain seed, the cost of re-establishing plantain into existing pastures, and different sowing rates of plantain seed to establish plantain into existing pastures. These variables only change the slope of the equations, with the trigger point remaining constant and the Solver add-in not being required.

These scenarios were repeated for the three targets of 20, 25 and 30% plantain in pasture averaged across the farm. All results represent a steady state situation (after T years), costs are a $/ha value for an individual year.

**Results**

Assuming a $500/ha cost of pasture renewal, changing the rate of pasture renewal had little impact on the cost of achieving the three targets, with the total costs remaining similar irrespective of whether the pasture renewal rate was 5, 10 or 15% per year. The total costs were approximately $100/ha, $140/ha and $185/ha to achieve the 20, 25 or 30% target plantain percentages on farm.

With increasing amount of plantain establishing in new pastures and plantain survival, the cost of achieving the targets decreased linearly (Figure 3a,b). It was not possible to achieve 30% plantain across the farm with <30% plantain establishing in new pastures or with <60% survival rate. There was little decrease in cost after achieving 20% plantain re-established into existing pastures. Conversely, there was a large increase in cost when only low amounts of plantain established. Plantain contents of 25% - 30% total DM across the whole farm could not be achieved if only 5% plantain re-established into existing pastures (Figure 3c).

**Figure 3.** Sensitivity of cost/ha to (a) percentage of plantain establishing in new pastures, (b) net percentage of plantain surviving from one year to the next, and (c) percentage of plantain establishing in existing pastures, to achieve 20% (single line), 25% (dotted line) and 30% (double line) plantain averaged across a farm.

Costs increased linearly with increasing cost of plantain seed, cost of re-establishment and the sowing rate of seed to achieve 12% of plantain establishing into existing pastures (Figure 4). Costs were most sensitive to the cost of re-establishment, followed by sowing rate into existing pastures and lastly cost of plantain seed. The three variables tested in these scenarios were scaling factors, so the trigger point for re-establishing plantain remained the same.

**Figure 4.** Sensitivity of cost/ha to (a) cost of plantain seed, (b) cost of re-establishment, and (c) sowing rate for re-establishing plantain into existing pastures, to achieve 20% (single line), 25% (dotted line) and 30% (double line) plantain averaged across a farm.
Discussion

The results support the hypothesis that the success and cost of plantain re-establishment into existing pastures have the largest impact on costs to maintain a specific plantain content in pasture across a farm. The observed lack of persistence of plantain in productive mixed-species pastures (Stewart 1996, Tozer et al. 2017) means that a significant plantain re-establishment programme is required. The power relationship between amount of plantain establishing in existing pastures and cost of maintaining plantain in pasture (Figure 1c) means there is a strong incentive for research to identify methods that can achieve at least 20% plantain establishing into existing pastures, irrespective of the target plantain content. Indeed, poor establishment (e.g. 5%) will likely make achieving an average of 25% or 30% of plantain over the whole farm impossible (Figure 3c). Re-establishment of plantain involves sowing into existing swards or supporting natural reseeding. Particularly at higher plantain content targets, costs of re-establishment must be minimised (Figure 4b). Note, we did not include cost of herbicide for weed control. Only a limited number of herbicides are suitable, since plantain does not tolerate most herbicides (Gawn et al., 2012).

The results demonstrate that achieving 30% plantain was 1.5 to 2 times more expensive than achieving 20%. Therefore, it is important to understand the minimum percentage of plantain in pasture required to achieve reductions in nitrate leaching in line with regulatory limits or water quality targets. The percentage of plantain establishing in new pastures, and the survival rate of plantain were also important factors, with costs ranging from $20/ha to $164/ha.

Acknowledgements

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References


Irrigation Insight: Co-innovating better water management practices in Canterbury

Alex Fear¹, Paula Blackett¹, Lan Chen², Toni White³, MS Srinivasan¹, Carla Muller and Stephen FitzHerbert¹

¹ National Institute of Water and Atmospheric Research (NIWA), Hamilton 3216, New Zealand
² AgResearch, Hamilton 3214, New Zealand.
³ Plant and Food Research, Hamilton 3214, New Zealand.

Dairying, irrigation, water. These three words produce sharply divided opinions across the population of Aotearoa New Zealand. A number of public voices go so far as claiming the dairy industry has lost its social licence to operate. At the heart of this challenge are the matters of water use, water quality and animal welfare. The Ministry of Business, Innovation and Employment (MBIE) funded Irrigation Insight programme aims to improve irrigation management by co-innovating practical tools with farmers and other relevant stakeholders such as industry and regulators, to enhance their (farmers’) ability to better manage irrigation water-use on farm to be economically sound and environmentally responsible. The co-innovation approach brings together farmers, scientists, industry organisations and government bodies. Irrigation Insight is a new idea that sits within a complex social, biophysical, economic and regulatory context. By including stakeholders in the co-development and co-design of potential solutions to better manage water-use, the final product(s) promises to be far more adoptable and practical, and therefore enhance uptake amongst farmers. One of the key components of this research programme is the communication of farmer narratives pertaining to environmental commitment and on-farm management changes to water use.

Social licence to operate is a relatively new concept internationally and in Aotearoa New Zealand. Its origin is mostly in the mining industry and has been applied to other industries more recently. While definitions vary across authors, industry and geographical context, there is consensus that at the heart of social license is the notion that an industry receives the approval of local communities and other stakeholders in relation to some form of activity (e.g. fisheries, aquaculture, dairy, and mining). Many authors’ frame social licence to operate as an outcome, rather than a process or method to achieve an outcome. In terms of generating social licence to operate, key authors point to the importance of relationships between industry and the public and other stakeholders. As summarised by Quigley and Barnes (2014: 4), a number of key components in positive relationships to enable social license to operate include:

- Openly shares information;
- Actively networks and engages (not passive);
- Has developed a shared understanding;
- Delivers on commitments made.

Across these aspects is the underlying notion of a two-way relationship, in which both sides need to engage with each other.
Within New Zealand the social licence to operate agenda has largely been applied to aquaculture and fisheries (Quigley & Barnes, 2014). Dairying is a more recent focus of attention (e.g. Woodward, 2017). This has largely emerged from heightened environmental concerns pertaining to water quality and water use, particularly in the Canterbury region. Industry stakeholders have dedicated considerable resources to better communicating how they operate. However, the current relationship between the dairy industry and the wider New Zealand public is tense, which has been amplified by the increasing effects of public media and social media platforms.

The notion of social licence to operate entered the Irrigation Insight programme through the research team’s conversations with farmers. It was not an explicit focus of the research programme. However, during interviews and within workshops, farmers themselves expressed their commitment to being transparent and informing the public about their farm management as well as their reasons for participating in Irrigation Insight. As a co-innovation project, farmers inform the process and outputs of the research programme. As such, farmers commitment to communicating their stories to the wider public is a core aspect of the programme. In particular, farmers discussed the following matters in regard to public perceptions of dairy farming in Canterbury:

“It’s getting the public to understand that actually, we are making the best effort to make the best use of water... and that we are actually caretakers as well as managers and that we are wanting to do the best. We are not out there trying to pillage everything for our financial gain, because a lot of us are long termers like myself, born to it” (Farmer A, 2018).

And, another farmer mentioned:

“I think the risk can be fairly high from a public perception level. Honestly, it’s a very highly talked about topic in the media so we need to be doing the best we can. There is a lot of talk around degradation to streams and rivers and bits and pieces” (Farmer B, 2018).

As such, public opinion is important to this group of farmers (as with other farmers). Through their participation in the Irrigation Insight programme, they want to share their stories of water management and any changes they make with wider audiences to foster greater understanding of dairying.

The research programme is charged with developing media and communication tools to facilitate the sharing of these farmers’ stories of environmental commitment and the process of making sustainable changes on farm. As such, we aim to develop tools that help inform and generate positive relationships with the public and other stakeholders. To date the programme has produced a series of communication tools, including a recently launched website. As the programme continues, the research team will investigate and develop tools for bringing different groups together in order to foster better understandings of farmers’ water management practices. These tools have not yet been defined and will emerge through the process of co-innovation.

In this presentation, the authors will provide an overview of the applied co-innovation process and discuss the challenges and opportunities of this approach within the research programme and the overarching aim of better enabling sustainable water management. The authors will discuss one of the media outputs of this project, which encapsulates the commitment and complexity of water management changes. Ultimately, the project envisages creating a platform for
improved integrated water quantity-quality management. A commitment within this project is to better publicise farmers’ commitments and efforts to improve water management and enhance local environments.

References


Long-term growth of cattle reared on a concentrate or forage starter diet

V. T. Burggraaf*a, M. A. Khanb, K. A. Lowec, P. D. Muirc, B. C. Thomsonc, S. A. McCoardd

*aAgResearch, Ruakura, Hamilton, New Zealand
bAgResearch Grasslands, Palmerston North, New Zealand
cOn-Farm Research, Hawkes Bay, New Zealand
*Corresponding author. Email: vicki.burggraaf@agresearch.co.nz

Abstract

This study evaluated the feed cost and long-term growth of Wagyu x Holstein Friesian calves reared either on a forage starter (FS, ensiled Lucerne, Medicago sativa; 45% DM, 19% CP, 9.7 MJ ME/kg DM) or a concentrate pelleted starter (CS; 90% DM, 19% CP and 13.8 MJ ME/kg DM) diet, followed by a forage-only diet. Calves (n=60) were allocated to either FS or CS diets and fed 2 L reconstituted whole milk/calf twice daily until week 7 and then once daily until week 9. Calves received their starter feeds ad libitum until transferred to pasture (week 8), then starter feeds were removed gradually by week 15, thereafter all cattle were managed as one mob on forage. Calves consumed 80.3 kg DM for CS and 67.9 kg DM for FS diets. The CS calves had a 14 kg liveweight advantage over FS calves (P<0.001) at week 15. Thereafter, CS calves grew slower than FS calves to 10 months of age (0.44 vs. 0.52 kg/day; P<0.001), with similar liveweights between treatments from 10 to 26 months of age. The feed cost was $11 more per calf for CS than FS. Calves can therefore be reared at low cost on a forage based starter without compromising long term growth on pasture.

Keywords: calf rearing, economics, liveweight

Introduction

Calf diets vary in cost (Muir et al. 2000) and can have long-term consequences on cattle growth (Berge 1991). In New Zealand, calves originating from dairy farms are fed a milk-based diet, typically supplemented with concentrate to promote rumen development (Khan et al. 2016) and hence facilitate early weaning onto pasture. Inclusion of forage in the diets of concentrate fed calves improves their rumen development and promotes solid feed intake during and after weaning (Khan et al. 2011; Castells et al. 2013). However, the long-term growth of calves on pasture, after rearing exclusively on forage or concentrate starter diets is unknown. This study compared the economics of rearing calves either on a forage starter (FS, ensiled Lucerne, Medicago sativa) or a pelleted concentrate starter (CS), and the effects on growth to two years of age in a pastoral system.

Materials and methods

This research was approved by the AgResearch Grasslands Animal Ethics Committee (AE12384) and conducted in compliance with the Animal Welfare Act of 1999 of New Zealand, and its amendments.

Wagyu x Holstein Friesian heifer calves (n=60, 4-14 days old) were sourced from two farms across three dates in August 2014. Calves were assigned to one of two dietary treatments (FS; forage starter or CS; concentrate starter), balanced for liveweight, arrival date and farm of origin. The CS
calves received a 20% protein pelleted calf starter (Denver Stock Feeds, Palmerston North, New Zealand) and FS calves were fed FiberStart® (Modified Bio-Fermentation Lucerne high nutritional fiber HNF®, Fiber Fresh Feeds Ltd., Reporoa, New Zealand). Calves were housed in groups of ten with free access to fresh water. All calves were fed 2 L reconstituted whole milk powder (WMP) at 125 g/L twice daily for 7 to 9 weeks, reducing to once daily when individuals had gained a minimum of 18 kg liveweight, then were weaned off milk two weeks later. Calves had ad libitum access to their respective solids feeds until one week after starting once-a-day milk feeding, when they were transferred to pasture. Solid feeds were gradually reduced over the following five weeks. All cattle were then managed in one group on a forage-based diet.

Solid feed DM intake was measured for each treatment from week 1 to 15 as the difference between refused and offered feed. Each batch of FS and CS feed was analysed for nutritional composition, via wet chemistry, by Hill Laboratories, Hamilton, New Zealand. Individual animal liveweight was measured on day 0, weekly until 16 weeks, fortnightly until 10 months then monthly until 26 months.

Economic margins for calf rearing were calculated as sale price at 15 weeks (when all calves had transitioned to a pasture only diet), minus feed costs and initial calf purchase price ($NZ150/calf). Sale price at 15 weeks was set at $NZ450 for a 90 kg calf, with an adjustment of ± $1.50 per kg liveweight above or below 90 kg (FirstLight Wagyu Ltd., New Zealand). WMP was priced at $NZ3500 per tonne and calf meal at $NZ800 per tonne. A comparison of commercial prices (https://store.nzfarmsource.co.nz) showed Fiberstart® averaged 90% of the cost of concentrate based pelleted calf starters and hence the Fiberstart® price was set at $NZ720 per tonne. Statistical analyses were performed in R (R Core Team 2016) using a mixed effects model, with repeated measures for liveweight. Treatment was included as a fixed effect and source farm as a random effect. Arrival weight and date were used as covariates for analyses.

**Results and discussion**

The CS calves consumed an average of 28.3 kg WMP on a DM basis, compared to 29.8 kg for FS calves. The CS diet comprised 90% DM, 19% CP, 16.2% NDF and 13.8 MJ ME/kg DM, whilst FS comprised 45% DM, 19% CP, 40.3% NDF and 9.7 MJ ME/kg DM. Total DM intake of solid feed averaged 80.3 kg for CS calves and 67.9 kg for FS calves. The CS calves grew faster than FS up to week 15 (0.60 vs 0.48 kg/day, respectively, SEM 0.015, P<0.001), reflecting their greater DM intake and the greater ME content of their diet. This resulted in a 14 kg liveweight difference at 15 weeks, when solid feed was removed.

Table 1. Liveweight (kg) of cattle reared on either a pelleted concentrate starter (CS) or a forage starter (FS) diet for up to 15 weeks, then grazed together on a forage diet.

<table>
<thead>
<tr>
<th>Age</th>
<th>CS</th>
<th>FS</th>
<th>Average SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 weeks</td>
<td>32</td>
<td>32</td>
<td>1.78</td>
</tr>
<tr>
<td>15 weeks</td>
<td>97</td>
<td>83</td>
<td>1.77***</td>
</tr>
<tr>
<td>5 months</td>
<td>117</td>
<td>107</td>
<td>1.80*</td>
</tr>
<tr>
<td>10 months</td>
<td>174</td>
<td>173</td>
<td>1.78</td>
</tr>
<tr>
<td>18 months</td>
<td>375</td>
<td>371</td>
<td>4.93</td>
</tr>
<tr>
<td>26 months</td>
<td>436</td>
<td>443</td>
<td>3.59</td>
</tr>
</tbody>
</table>

For differences between treatment means, * = P<0.05, *** = P<0.001.
Because of greater DM intakes, the cost of rearing was $NZ11 greater per calf for CS than FS. However, the profit during rearing was $NZ11 greater (SED 4.58, P<0.01) for CS than FS calves, due to their greater liveweight, and therefore higher sale price at 15 weeks ($NZ457 vs $NZ435, respectively, SED 3.65, P<0.001).

Following rearing, CS calves grew slower than FS calves to 10 months (0.44 vs 0.52 kg/day, respectively, SEM 0.014, P<0.001), with similar liveweight for both treatments from 10 to 26 months (Table 1). This could be due to either compensatory growth (Lawrence et al. 2012), or to the FS diet stimulating rumen development (Castells et al. 2013) to better prepare calves for a pasture-only diet. The similar liveweight of FS and CS cattle from 10 to 26 months indicates that the forage based starter diet could be used as a low cost option to rear calves for pastoral production systems without negatively affecting their long-term growth.

Acknowledgements
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References
A comparison of future dairy farm systems in Manawatū and Canterbury regions of New Zealand

T Parminter*, MD Apparaoa, A Dooley and GTraffordb

aKapAg Ltd, Paraparaumu, New Zealand; bMassey University, Palmerston North, New Zealand;

*Corresponding author. E-mail: terry.parminter@kapag.nz

Abstract

Designing future farming systems which are resilient in an increasingly volatile environment is challenging and new approaches are needed that capture industry creativity in response to political, social and economic pressures. One approach to addressing this challenge is using scenario planning as the basis of farm systems design. In a previous phase of this project, three distinct future world scenarios were developed – Consumer is King, Governments Dictate and Regulation Rules. In this part of the project, dairy farm systems for each of these future scenarios were developed at workshops with local dairy farmers. Possible regional differences were explored by conducting each pair of workshops separately in the Manawatū (Massey University) and Canterbury (Lincoln University) regions. At the workshops, participants made explicit in group exercises their mental models conceptualising possible future farm systems for their region under each of the three scenarios. This paper identifies and describes the similarities and differences between the future dairy farm systems for the Manawatū and Canterbury regions under each of the three scenarios. In general, the farm systems were largely similar between them for the GD scenario but there were regional system differences under the CK and RR scenarios.

Keywords

scenarios; participatory planning; mental models; farm management; 2025

Introduction

Designing resilient future farming systems in increasingly volatile and uncertain business and natural environments is challenging. While farm systems modelling often extrapolates the future from the current situation, this approach may not be ideal given the uncertainty and volatility inherent in the industry. Schoemaker (1993, 1995) suggested scenario analysis could be a useful approach in such circumstances. It has previously been used in an agricultural context both overseas (Dairy Australia 2013) and in New Zealand (Parminter et al. 2003), and was applied in this study.

In the first phase of this dairy farm systems project, four distinct future world scenarios impacting on New Zealand dairying were developed at farmer and industry workshops at both Lincoln and Massey Universities (Shadbolt et al. 2015). These were a consumer-driven ‘Consumer is King’ scenario, (CK) a highly regulatory ‘Regulation Rules’ scenario (RR) a political chaos based ‘Governments Dictate’ scenario (GD) and a base scenario which was extrapolated from present trends.

In the second phase of this project, dairy farm systems for the three alternative scenarios were developed by stakeholders at Lincoln (Canterbury) and Massey (Manawatū) Universities. This paper provides an overview of the significant similarities and differences between Manawatū and Canterbury dairy farm systems for each of the three alternative scenarios.

Methods
A detailed explanation of the methodology used, its rationale and limitations are provided in Dooley et al. (2018). In brief, this study was based around two workshops held at each university in 2015; a farmer workshop followed by an industry workshop. At each of the workshops, participants working in groups were asked to make explicit their mental farm system models in response to each scenario (Vennix 1996). This paper describes the results of the farmer workshops.

Results and Discussion

**Consumer is King**

In this scenario, by 2025, the world has had considerable economic growth. Driven by wealthy and fickle consumers, food has become another status symbol. The food market is highly diversified, complex and rapidly evolving alongside other fashion products. Niche supply chains develop around peoples’ values and their need to know where food has come from and how it is being produced.

The farmers at both Massey and Lincoln considered that in this scenario there would be more corporate farms although Massey farmers expected ownership to include a range of different options including opportunities for smaller farms or group of farmers with niche supply chains. Farming systems would be increasingly diverse and flexible. Farmers expected more production to be contracted to meet market specifications for products and their production attributes. Some farmers expected the dairy industry to be vertically integrated with processors and exporters having a financial interest in the farm production systems. Other farmers with niche milk products could have their own supply chain directly linked to consumers. Farms would produce milk all year round. Diverse cow breeds and feed stuffs would result in milk of different qualities. High standards of animal health, animal welfare and working conditions (e.g. 40hr working week) were required.

The Massey farmers designed grass-based systems as soft systems models (Checkland 1999) with some specialist feeds and nutrients brought-in. Lincoln farmers considered that these cows would be housed for greater farm automation, animal monitoring and control. The housed cows would require cut-and-carry pasture and diverse feeds. They also suggested genetically modified pastures would be used, along with ‘natural’ plant nutrients and biological control of weeds and pests.

Massey and Lincoln farmers expected their farm staff to be highly skilled and able to draw on technical specialists. Massey farmers assumed that farms would be fully automated whereas Lincoln farmers expected there to be a lot of semi-skilled labour on contract. In both cases working conditions for staff would be improved (e.g. 40hr week).

**Governments Dictate**

By 2025, World political instability is common with concerns regarding food security. Trade is highly protected and food aid has become large scale. Consumer demand is for basic, nutritionally-dense foods and the margins for agribusiness firms are slim. In response to this scenario, farmers at the Massey and the Lincoln workshops both designed corporate-owned larger farms, with high stocking rates and low costs of production. Both farmer groups expected continued increases in milk production per cow. They also expected genetically modified species in pasture-based systems to improve drought resistance and nutrient-use efficiency.

Both Massey and Lincoln farmers relied on the availability of new technologies to improve farming efficiency. Managers on their farms would be highly skilled in farm management and new technology, and would be able to draw on off-farm technical specialists in IT, robotics, HR, compliance and PR. Semi-skilled labour was expected to be sourced by immigration, and working
conditions included a 40-hour week. The Massey farmers expected the introduction of fully irrigated farm systems with on-farm water storage. The Lincoln farmers expected the cows in their system to be selected for beef as well as milk production.

**Regulation Rules**

By 2025 world trade has continued to expand, facilitated by multi-lateral trade agreements. There has been high economic growth world-wide and an expanding middle-class in developing countries. However, there is more stringent regulation and greater monitoring of supply chains with a focus on food safety, the environment, animal welfare and labour relations.

In response to this scenario, the farmers at Massey and Lincoln thought that a number of business structures would be possible including corporate and family farms. They expected farms to have reduced stocking rates and increased costs from the addition of-farm monitoring and data-collection. Highly skilled managers, with access to technical specialists were required for these farms. Working conditions were expected to have been improved and all farm staff would be working a 40-hour week. Farmers expected these farms to have considerable technology to automate monitoring and provide proof of process. They would need to have a high level of transparency, full traceability and full third-party auditing.

Massey farmers considered that under this scenario dairying would be restricted to only a few regions in New Zealand where the environmental impact would be relatively low. They expected the industry to have seasonal calving, whereas the Lincoln farmers expected calving to be all-year-round. Both farmer groups expected cows to be in good condition all year round, meeting high animal health and welfare standards. All calves would be reared as either herd replacements or sold on for beef production. Both Massey and Lincoln farmers expected the farming systems to be grass-based with increased dry matter production from forage crops, grain crops and maize silage. Massey farmers expected there to be widespread introduction of irrigation in their region.

**Conclusion**

This study found considerable similarity between the expectations of farmers in the Manawatū and Canterbury regions for the farm systems under the GD scenario. This similarity may reflect that when governments intervene in market supply networks and production systems, farmers consider that their future options for innovation will be particularly constrained.

The similarities between the regions was less for the RR and CK scenarios, and the greatest differences were when consumer expectations were the most diverse (in the CK scenario). Industry, research and policy organisations supporting the adaptation of dairy farm systems through to 2025 will need to take into account the diversity of farm systems responding to the different drivers described in these scenarios. Depending on the drivers and the regions involved, there may be growing diversity in farm systems between regions.
Acknowledgments

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References


Short-Term Dry Matter Intake and Body Weight Changes of Dairy Cows

Dry matter intake and weight changes of cows

School of Life and Environmental Sciences, The University of Sydney, Camden Campus, NSW 2570, Australia
Corresponding author. email: mardhati.mohammad@sydney.edu.au

Abstract

This paper focuses on the changes in animal’s body weight (BW) while consuming feed in real-time in dairy cows. Cows were offered 4 kg of Lucerne cubes as fed (DM=88%), twice daily for 5 days in a scale box. One week prior to the actual experiment, the cows were adapted to the experimental protocol by undergoing repeated weighing activities and fed while on the scale. Weight on the scales was recorded at 4 Hz from the time cows stepped on the scale until the end of eating. Total individual DMI estimated by body weight changes (weight before and after eating) were compared with the amount of feed consumed. Cows that defecated and urinated during cube feeding were excluded from data analysis. Overall, BW increased with food consumed, as expected. However, DMI was underestimated by 15% on average, with a mean estimated intake value of 3.39 kg (± 0.25 kg, cv=7.44%). Interestingly, the error increased as BW increased, from about 10% for 660-kg cows to about 25% for 710-kg cows. Results from this experiment indicated that as BW of cows increases then the accuracy of the weighing scale to predict DMI decreases. These results have helped to improve knowledge on the BW changes due to short-term DMI.

Keywords

dry matter intake; weight changes; dairy cows

Introduction

Dry matter intake (DMI) is one of the key determinants of animal performance, as it supplies all the nutrients required for production and reproduction which contribute to the farm profitability. The amount of intake is affected by various factors including animal, feed and environmental factors. As highlighted by Vazques (2000), 71% of the DMI variance is contributed by animal characteristics (body weight (BW), change in BW and fat corrected milk). Therefore, intake models have been developed by different researchers, such as Caird and Holmes (1986), NRC (2000) and Baudracco et al. (2012) to predict DMI based on those characteristics. However, the accuracy of the animal-based intake model especially using BW data is a challenge as discussed by Huhtanen et al. (2011); Krizsan et al. (2014) and Jensen et al. (2015). It is difficult to accurately predict DMI due to high fluctuation in BW between and within animals diurnally and even hourly. A thorough understanding of the relationship between DMI and BW changes (BWC) is required to increase the accuracy of intake prediction models. Thorup et al. (2012) assumed that variation in individual BW is mainly attributed to milk in the udder and meal-related gutfill. These effects can be accounted for by weighing cows at the same time every day after the morning milking. However, fluctuations still exist due to unknown reasons. We conducted a preliminary study to better understand the association between DMI and...
real-time BW changes in dairy cows to improve DMI prediction models with hypothesis that a cattle scale would be able to capture the changes in BW due to eating.

**Materials and methods**

A preliminary study was conducted at the University of Sydney research farm Mayfarm, Camden, New South Wales, Australia. A total of 5 Holstein-Friesian dry cows were offered 4kg of Lucerne cubes as fed basis (DM=88%), twice daily for 5 days while in a scale box (2.0m L x 0.6m W, Gallagher load bar cell (2,000kg) and TW1 indicator, NZ) with total 25 observations (5days x 5 cows). Dry cows were used in this experiment to minimize the influence of BW changes (e.g., milk production). One week prior to the actual experiment, cows were adapted to the experimental protocol by undergoing repeated weighing activities and fed while on the scale, followed by 5 days of data collection. Weight on the scales was recorded at 4 Hz from the time cow stepped on the scale until she finished eating. Weight data were automatically transferred to a laptop computer (Dell Latitude E5570). Ten data points of BW of dairy cows before they started eating were averaged to estimate the initial weight. Cow BWC was calculated for each observation subtracting the BW of the previous observation from the BW of the actual observation. Each BWC observation was classified as an ‘increment due to eating’’ if it was greater than 0.1 kg (minimum resolution of the scale) and cows tend to eat 150-200g/m in. Otherwise, the observation was considered ‘no eating’. These BWC were added to get the predicted total intake. Individual daily observations where defecation or urination occurred during cube feeding were excluded from data analysis. Individual intake (DM basis) was also compared with the actual intake value. Each individual measurement was considered as independent variable and not correlated because residuals were randomly distributed. This allows the calculation of the descriptive statistics.

All experimental procedures were approved by the University of Sydney’s Animal Ethics Committee (AEC, 2017/1213).

**Results**

The patterns of dmi and average intake for 5 days for individual dry cows are illustrated in Figure 1 and 2, respectively. Overall, daily BW increased with food consumed as expected (Figure 1) indicating that BW changes happened due to short-term DMI.

![Figure 1. Daily estimated DMI (kg) versus BW of individual cows (kg)](image-url)
While, table 2 shows changes in average predicted DMI with body weight of individual cows while eating. DMI was underestimated by 15% or 3.39 kg on average (±0.25kg, cv=7.44%). Interestingly, results also indicated that the error increased with BW (Figure 2), from about 10% for 660-kg cows to about 25% for 710-kg cows.

![Figure 2. Changes in average predicted DMI with body weight of individual cows while eating.](image)

**Discussion**

Results from this experiment indicated that BW of cows affect the accuracy of the weighing scale to predict DMI from changes in real-time BW of dairy cows while eating, with lower accuracy for heavier cows. It is contrary to the hypothesis that a cattle scale could capture the changes in BW due to eating. Factors contributing to this error are not clear. It could be due to movement of the cows during weighing or the accuracy of the scale. The weighing scale box might be too small for the big cows because the back of the cows frequently touches the rear gate, which transfers some of the weight to the gate instead of the scale load-bars as the rear gate wasn’t on the load-bars.

Further research with more cows should be undertaken to validate these results and, also to study the hourly and daily BW pattern of individual animals. It will include defecation and urination with the bigger set up of scale box to better understand how input and elimination activities affect short-term BW changes of dairy cows and ultimately improve prediction of DMI.

**Acknowledgements**
The authors would like to thank Mrs Sherry Catt, former administrative assistant, The University of Sydney for her wonderful advice and help on various technical issues and also Md Ashraful Islam, PhD student at University of Sydney for his support and assistance.
References


Changes in bite mass and eating rate were measured in cows as pasture mass declined during a grazing event. Four groups of 20 Holstein-Friesian cows were fitted with jaw movement recorders (Rumiwatch Noseband Sensor, ITIN+HOCH GmbH, Switzerland). Over three days in spring, when cows were in early lactation, grazing behaviour was monitored in each of the four groups in separate paddocks during a 5-hour grazing period after the morning milking. The initial mass of the perennial ryegrass pasture was 4400 kg DM/ha (to ground level) and this was re-measured each hour using a rising plate meter. Pasture disappearance was used to calculate bite mass. Bite mass in the first hour of grazing averaged 1.2 g DM but declined to a low of 0.4 g DM thereafter. Similarly, bite rate declined from 3116 to 780 prehension bites/h, grazing time declined from 58 to 20 min/h and intake rate declined from 3.6 to 0.4 kg DM/h after the first hour of grazing. In contrast, ruminating time increased from 1 min/h in the first hour of grazing to a high of 20 min/h thereafter, while idle time increased from 2 min/h to 22 min/h. Information such as this could enable on-cow sensors to be used to estimate pasture intake in grazing cows in near real time.

Introduction

The measurement of dry matter intake (DMI) in grazing dairy cows has been a challenge for farmers and researchers alike for many decades. Understanding the dry matter and nutrients that cows receive from pasture is essential for determining the nutrient supply required from supplements for optimal milk production. A commonly used method for measuring DMI in a research context is the n-alkane technique (Dove and Mayes, 1996), however it is labour intensive and requires complex and lengthy chemical analyses of pasture and faeces, rendering it useless for day-to-day management of cow diets.

To address the need for a near-real time estimation of DMI in grazing cows, previous researchers have attempted to use on-cow activity meters to measure grazing time as a surrogate estimate of DMI. These methods have proved imprecise because they fail to take account of variations in total number of bites per day and the amount of herbage dry matter harvested with each bite (Barrett et al. 2001). More recently, on-cow sensors have been developed that can measure the number of jaw movements each cow makes per day, and which can distinguish between prehension bites and jaw movements related to rumination and mastication. These sensors take a step closer to being able to measure DMI of grazing cows, but intake is a product of number of bites and bite mass (Allden and Whittaker, 1970), and measuring bite mass in the field is problematic (Stobbs, 1973).

The study reported here had the aim of generating information about the variation in bite mass in grazing cows, and how bite mass changes as pasture mass declines during grazing, as the first step to assessing whether bite mass and number of bites could be used to estimate DMI.
Materials and methods

The current experiment was part of a larger, early lactation experiment in which 80 Holstein-Friesian cows grazed perennial ryegrass pasture supplemented by 9 kg DM/cow.d of a mixed ration containing canola meal, wheat grain, barley grain and maize grain (the ration was split into two equal parts and fed in the dairy after each milking).

The 80 cows were allocated into four groups of 20 cows. Grazing behaviour was monitored using jaw movement recorders (Rumiwatch Noseband Sensor, ITIN+HOCH GmbH, Switzerland) in one group at a time on three consecutive days each. On each day, measurements were made during a 5-hour grazing period after the morning milking.

At each grazing, cows entered a fresh paddock of pasture, the initial mass of which averaged 4400 kg DM/ha (to ground level). Pasture mass was re-measured each hour using a rising plate meter; pasture disappearance was used to calculate bite mass.

Data were analysed using GenStat 18 (2015). Differences between mass data and grazing behaviour parameters were determined by general ANOVA, with treatment hour blocked by replicate, and Duncan’s multiple range test conducted. Differences of $P < 0.05$ were considered significant.

Results

Time spent eating was greatest in the first hour after cows reached the paddock when cows spent nearly their entire time grazing. Grazing time per hour declined thereafter, with concurrent increases in both ruminating time and idle time ($P < 0.001$; Figure 1).

![Figure 1](Image)

Figure 1. The average time cows spent grazing, ruminating or idle each hour.

Pasture mass decreased as grazing progressed and the total amount of pasture removed each hour progressively decreased (Table 1). After 5 hours' grazing only 68% of available pasture
remained. Intake rate, bite rate and bite mass were greatest in the first hour and decreased thereafter (trend only for bite mass, \( P = 0.063 \)).

Table 1. Pasture mass, intake rate, bite rate and bite size after the first hour of grazing. Data are means of three days for four reps over a 5-h grazing session.

<table>
<thead>
<tr>
<th>Hour</th>
<th>Pasture mass (kg DM/ha)</th>
<th>Pasture mass/plot (kg DM)</th>
<th>Pasture removed/h (kg DM)</th>
<th>Intake (kg/cow. h)</th>
<th>Prehension bites/cow.h</th>
<th>Bite mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4415c</td>
<td>316c</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>3428b</td>
<td>245b</td>
<td>71b</td>
<td>3.6b</td>
<td>3116c</td>
<td>1.2</td>
</tr>
<tr>
<td>2</td>
<td>3234ab</td>
<td>232ab</td>
<td>14a</td>
<td>0.7a</td>
<td>1634b</td>
<td>0.4</td>
</tr>
<tr>
<td>3</td>
<td>3079ab</td>
<td>219ab</td>
<td>13a</td>
<td>0.7a</td>
<td>785a</td>
<td>0.7</td>
</tr>
<tr>
<td>4</td>
<td>3029a</td>
<td>219ab</td>
<td>14a</td>
<td>0.7a</td>
<td>968a</td>
<td>0.7</td>
</tr>
<tr>
<td>5</td>
<td>2908a</td>
<td>206a</td>
<td>11a</td>
<td>0.5a</td>
<td>974a</td>
<td>0.5</td>
</tr>
<tr>
<td>s.e.d.</td>
<td>156.4</td>
<td>14.6</td>
<td>8.7</td>
<td>0.4</td>
<td>216.0</td>
<td>0.2</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.063</td>
</tr>
</tbody>
</table>

**Discussion**

These data indicate a substantial variation in average bite mass as grazing progressed. Numerically, average bite mass during the first hour of grazing was two to three times greater than for the rest of the 5 hours. After the first hours’ grazing, average bite mass was much more consistent, ranging only between 0.4 and 0.5 g/bite. The trend for a reduction in bite mass after the first hour was accompanied by a decline in pasture mass as pasture was consumed. The largest drop was during the first hour after the cows returned to the paddock, during which time 23% of available pasture was removed and the pasture mass was reduced from 4400 to 3450 kg DM/ha. Thus the results of the current experiment were in accordance with the previous experiment of Laca et al. (1992), which showed that bite mass in grazing dairy cows was related both to the mass and density of the pasture on offer, and that bite mass increased with taller, sparser swards than shorter denser swards. Laca et al. (1992) also reported that the initial bites of cows grazing ‘reconstructed’ grass pasture ranged in mass between 1.6 and 1.9 g DM. This is also in agreement with the average bite mass in the first hour of the current experiment.

The rate of intake of pasture in the current experiment was also markedly greater in the first hour after the cows returned to the paddock than for the rest of grazing. This can be explained by the greater bite mass described above, in combination with the bite rate (number of bites per hour) also being markedly greater in the first hour than during the rest of the grazing. Given that all cows had consumed approximately 4.5 kg DM of mixed ration in the dairy during milking, it is perhaps not surprising that the time they spent grazing and bite rate both dropped off rapidly after the first hour.

Overall these data provide an indication that plant factors related to initial pasture mass and cow factors related to time since the commencement of grazing could have important influences on the
mass of grass harvested by cows with each bite. Barrett et al. (2001) concluded that the plant factors related to pasture mass were more important, but a greater understanding of these relationships will be required to predict bite mass with sufficient accuracy for the assessment of the DMI of grazing cows. Presumably the variation in bite size between individual cows will be even greater than for the group averages reported here; understanding this individual cow variation would be an appropriate starting point for further research.

References


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**VitiFeed made from steam distilled grape marc can be included at 10% of the dairy cow diet with no reduction of milk production**

Brendan Cullen\(^1\), Brenton Mengersen\(^2\), Jeremy Desfreres\(^3\), Frank Dunshea\(^1\), Kenny Oluboyede\(^1\), Nick Boyd\(^1\) and Long Cheng\(^1\)

\(^1\)Faculty of Veterinary & Agricultural Sciences, The University of Melbourne, Victoria 3010, Australia.

\(^2\)Tarac Technologies Pty Ltd, 20 Samuel Road, Nuriootpa, South Australia 5355, Australia.

\(^3\)AgroParisTech, Paris Institute of Technology for Life, Food and Environmental Sciences, France.

Corresponding author. Email: bcullen@unimelb.edu.au

Short title: Grape marc feeding to dairy cows

**Abstract**

An experiment to test the hypothesis that inclusion of steam distilled grape marc (‘VitiFeed’) at 10% of the dairy cows’ diet would not have a negative impact on milk production was conducted in a pasture-based dairy production system in northern Victoria, Australia. At the commencement of the experiment the cows were on average 70 days in milk and had a liveweight of 675 kg. Two groups of 18 cows were fed a diet consisting of daily offerings of 8.1 kg DM/cow concentrate feed (16% crude protein (CP) and 12.5 MJ ME/kg DM), approximately 5 kg DM/cow pasture and 8 kg DM/cow of silage. The control group received 8 kg DM/cow of silage made from balansia clover pasture (20.2% CP, 10.5 MJ ME/kg DM), while the VitiFeed group received 6 kg DM/cow of balansia silage and 2 kg DM/cow steam distilled grape marc silage (14.7% CP, 8.5 MJ ME/kg DM). Silage was fed on a feed pad, and refusal was estimated as <5% of silage offered. The experiment included a 7-day adaptation period followed by 35-days of data collection. Daily milk production, fat and protein percentages and rumination time were recorded using the Lely Astronaut milking machine. Treatment differences were analysed by ANOVA. There was no significant difference in milk production (37.8 vs. 38.8 kg milk/day, 2.73 vs. 2.74 kg milk solids/day) and rumination time (414 vs. 398 minutes/d) between the treatments (Control vs. VitiFeed). These results indicate that feeding VitiFeed to dairy cows at 10% of the diet can sustain milk production but further research is required to confirm this finding.

**Keywords:** Grape marc; dairy cows; silage; rumination; milk composition

**Introduction**

Grape marc (the skins, seeds, stalk, and stems remaining after grapes have been pressed to make wine) is a waste-product that may be used as a feed supplement in dairy production, but its nutritive characteristics can vary widely (Russo et al. 2017). Previous work showed that grape marc contains high levels of condensed tannins and crude fat (Moate et al. 2014). Feeding tannins to dairy cows has been demonstrated to decrease enteric methane, reduce urinary nitrogen loss and improved nitrogen use efficiency in the cows (Grainger et al. 2009) while including dietary oils in the diet of dairy cows can reduce their methane emissions and increased milk production where energy
was added to the diet (Moate et al. 2011). However, while grape marc either fed as dried, pelleted grape marc or ensiled to dairy cows can reduce their enteric methane emissions by around 20% when compared to a control diet of similar protein and energy, it also appeared to decrease milk yield (Moate et al. 2014). VitiFeed is a grape marc silage that undergoes a steam distillation process that reduces tannin levels (Hixson 2015) to improve palatability. The aim of this experiment was to determine if inclusion of a steam distilled grape marc ‘VitiFeed’ at 10% of DM intake would have a negative effect of milk production and composition of dairy cows.

Materials and Methods

Experimental design

The experiment was conducted at The University of Melbourne, Dookie campus dairy in northern Victoria, Australia. The farm consists of 41 ha of irrigated pastures, a feedpad and a milking herd of 155 Holstein-Friesian cows. The farm has a split calving pattern with two thirds of the cows calving in spring, and one third in summer/autumn. Cows are milked in a Lely Astronauts robotic milking system, with voluntary cow movement through three grazing areas to facilitate a target milking frequency of three times per day per cow.

A total of 36 cows were selected for the experiment from 60 cows that calved in the summer or autumn 2017. The cows were allocated into two treatment groups based on parity (3.7 ± 0.8), days in milk (67 ± 45) and average milk production (35 ± 5 kg/day) in the 7 days immediately prior to the experiment. At the commencement of the experiment, 6 of the 18 cows in each group were in the mid lactation period (117-145 days in lactation), while the remainder of cows were in early lactation (3-69 days in lactation).

The two treatments were: Control, where cows were fed as per normal feed management on farm (Table 1); and Vitifeed, where 2 kg of the balansia silage offered to control cows was substituted with VitiFeed (equivalent to 9.5% of DM intake). VitiFeed was provided by Tarac Technologies Ltd (Australia). The experiment commenced on 6 June 2017 and ran for 42 days (7-day adaption period plus a 35-day measurement period).

The two treatment groups were managed together with the main herd while grazing pastures in the morning and evening, but were divided into separate groups during the afternoon when the balansia silage and VitiFeed were offered daily to cows on the feedpad (approx. 1300 to 1800 h). Cows in Control and VitiFeed groups were drafted into separate areas of the feedpad. Balansia silage and VitiFeed were combined in the mixer wagon prior to being dispensed on the feedpad. The weight of silage dispensed was measured daily and the refusal amount was weighed daily. After the silage was consumed, the cows were returned to the main herd. The estimated intakes of dietary constituents are shown in Table 1 for each treatment. The nutritive characteristics of the balansia silage were estimated using near-infrared spectroscopy while for VitiFeed wet chemistry techniques were used for crude protein, digestibility, crude fat by acid hydrolysis and ME was estimated by:

\[
\text{ME} = 0.858 + (0.138 \times \text{Digestibility of Organic Dry Matter} \%) + (0.272 \times \text{Fat} \%)
\]

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All nutritive characteristic analysis was conducted by Agrifood Technology (Werribee, Victoria) and results are shown in Table 2. The concentrate fed contained 12.5 MJ ME/kg DM and 16% crude protein.

**Table 1. Estimated cow feed intake (kg DM/cow.day) during the 35 days measurement period.**

<table>
<thead>
<tr>
<th>Feed</th>
<th>Control</th>
<th>VitiFeed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrate</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Pasture</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Silage</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Vitifeed</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>22</td>
</tr>
</tbody>
</table>

**Table 2. Nutritive characteristics of the Balansia silage and VitiFeed used in the experiment.**

<table>
<thead>
<tr>
<th>Nutritive characteristic</th>
<th>Balansia silage</th>
<th>VitiFeed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein (% DM)</td>
<td>20.2</td>
<td>14.7</td>
</tr>
<tr>
<td>Acid detergent fibre (% DM)</td>
<td>28.2</td>
<td>n.a.</td>
</tr>
<tr>
<td>Neutral detergent fibre (% DM)</td>
<td>41.8</td>
<td>n.a.</td>
</tr>
<tr>
<td>Digestibility (% DM)</td>
<td>69.6</td>
<td>31.1</td>
</tr>
<tr>
<td>Estimated Metabolisable Energy (MJ/kg DM)</td>
<td>10.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Crude fat (% DM)</td>
<td>4.2</td>
<td>11.8</td>
</tr>
</tbody>
</table>

**Data collection and analysis**

The daily data collected per individual cow was averaged over the measurement period and used in the analysis of variance (ANOVA) using dietary treatment as a fixed effect and individual animal as a random effect. This included milk production (kg/day), fat and protein (%), liveweight (kg) and rumination time (minutes/day). Mean values recorded during the pre-experimental period were used as a covariate (where significant).

**Results and Discussion**

The percentage of the silage mixture that was refused by the cows was 5% in the control treatment (pasture silage only) and 2.5% in the control group.

There were no significant differences between the treatments in milk production (kg, fat and protein %, and milk solids), liveweight and rumination time (Table 3). There was also no trend in production differences over time during the experiment with milk production being similar across all weeks of the experiment. The finding that there was no negative impact of VitiFeed on milk production contrasted with the work of Moate et al. (2014) who found that cows fed ensiled grape marc produced less milk. One reason for this is likely to be that in the experiment of Moate et al. (2014) cows were fed 5 kg DM/day of ensiled grape marc (approximately 27% of the diet), which is higher compared to 2 kg DM/day in this experiment (approximately 10% of the diet).
Table 3. Mean daily milk production (kg/day), fat and protein percentage, liveweight (kg), and rumination time (minutes/day) for the Control and VitiFeed treatments. The least significant difference (l.s.d. $P=0.05$) is also shown. None of the treatment differences were significant.

<table>
<thead>
<tr>
<th>Units</th>
<th>Control</th>
<th>VitiFeed</th>
<th>l.s.d. ($P=0.05$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk production</td>
<td>Kg/day</td>
<td>37.8</td>
<td>38.7</td>
</tr>
<tr>
<td>Fat</td>
<td>%</td>
<td>3.88</td>
<td>3.95</td>
</tr>
<tr>
<td>Protein</td>
<td>%</td>
<td>3.32</td>
<td>3.24</td>
</tr>
<tr>
<td>Milk solids</td>
<td>Kg/day</td>
<td>2.70</td>
<td>2.77</td>
</tr>
<tr>
<td>Liveweight</td>
<td>kg</td>
<td>693</td>
<td>697</td>
</tr>
<tr>
<td>Rumination time</td>
<td>Mins/day</td>
<td>414</td>
<td>398</td>
</tr>
</tbody>
</table>

Overall this study indicated that VitiFeed can be added at 10% of the diet of dairy cows without any negative effect on milk production and milk composition but this conclusion is limited by weaknesses in the experimental design. Further research is required to confirm this finding using an experimental design that ensures independence between the dietary treatments and replication using groups of cows.

References


