Do baleage wintering systems improve cow comfort compared with fodder beet wintering? Soil conditions and behavioural responses of non-lactating dairy cows in Southland, New Zealand

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Abstract

Winter grazing systems in southern New Zealand can create wet, disturbed soil conditions that may restrict lying opportunities for non-lactating dairy cows. This observational study examined whether wintering practice influenced soil conditions and cow behaviour, with a focus on area allocation, baleage allocation frequency, and feed type (pasture baleage vs fodder beet). It was hypothesised that a larger area or reduced frequency of baleage allocation would reduce soil damage and improve lying times. Six groups of approximately 73 pregnant cows each were managed on six paddocks over 30 days (12 Jun –11 Jul, 2024). Five groups received pasture and baleage, under differing baleage allocation frequencies (daily or 3-day) or area allocation (6.7, 7.5 and 8.6 m^2/cow/day), while one group grazed fodder beet supplemented with baleage. Soil conditions (dry, wet, sodden) and behavioural measures (lying and rumination time) were recorded. There were no significant differences between treatments in soil wetness or lying time, with cows averaging 9.4–10.3 h/day lying. However, cows grazing fodder beet had 26–30% lower rumination than all other treatments viz, 420 vs 572-600 min/day. These findings suggest that, under the conditions studied, baleage wintering did not provide superior lying conditions compared with fodder beet. Reduced rumination with fodder beet feeding may have implications for animal health and subsequent milk production, warranting further investigation.

Keywords: rumination, lying time, pugging, surface pooling, winter

Introduction

Wintering non-lactating cows on forage crops in the southern regions of New Zealand is an important means of providing sufficient high-quality feed during cooler winter months when pasture growth is limited (Dalley and Geddes 2012) and soils are saturated. However, this wintering approach has come under increasing scrutiny from regulatory and public perception perspectives due to negative effects on soil structure, contaminant loss to water and animal welfare (Monaghan et al. 2017; Smith and Monaghan 2020; Neave et al. 2022). In addition, the implementation of wintering rules restricting the area and slope that can be planted in winter forage crops and buffer zone requirements (Environment Southland 2026) have resulted in farmers looking for alternative wintering options. These drivers have seen the emergence of baleage wintering across the Southland region. Under this regime, cows are wintered on pasture paddocks and offered up to 100% of their diet as conserved pasture (baleage or hay), with bales placed on the paddocks prior to winter (Simon et al. 2024).

While there has been rapid adoption of this wintering practice across the southern South Island since 2021 (from approximately 9% in 2021 to 19% in 2023, DairyNZ unpublished), there is limited information on the effect of bale density, pre-graze pasture mass, pasture species or feed allocation frequency on subsequent soil damage and animal comfort and well-being.

When determining how baleage wintering will be implemented, the total area required for the winter period is an important consideration. If wintering on the milking platform, the area allocated for wintering impacts the grazing area available for milk production in spring and if wintering on a support block it impacts the area available for other grazing activities. Consequently, baleage wintering is implemented using a wide range of management practices. Observed baleage bale densities from Southland range from 40-90 bales per bales per hectare (ha), corresponding to daily area allocations of approximately 12 to 6 m^2/cow/day. In contrast hay bale grazing systems are typically stocked at lower densities (equivalent to 16 m^2/cow/day) and cows are moved to a new area every 2-3 days (Schutz et al. 2024). Pre-graze pasture mass also varies from 2000 to 4000 kg dry matter (DM)/ha as does the proportion of the diet supplied as conserved feed.

Further research was needed to understand how these

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management factors affect soil physical conditions and animal behavioural indicators. Therefore, a study was undertaken at the Southern Dairy Hub (SDH) to assess the effect of different wintering practices on soil conditions and cow behaviour. Treatments differed in area allocation (bale density), frequency of baleage allocation and main feed type (pasture baleage vs fodder beet (FB)). It was hypothesised that a larger area or reduced frequency of baleage allocation would result in less soil damage and better lying conditions compared with cows wintered on fodder beet.

Materials and Methods

This study was conducted from 12 June - 11 July 2024, at the SDH research facility in Wallacetown, Southland, New Zealand (latitude: −46.31072, longitude: 168.30314). The experiment was located on two blocks of SDH, the milking platform and the associated support block (adjacent to, but separated from the milking platform by the Makarewa river). Paddocks on the milking platform were an Edendale typic firm brown soil, classed as well drained, with moderate over slow permeability and low N leaching vulnerability. The paddocks on the support block were predominantly Pukemutu; a poorly drained, silt-over-clay soil characterised by a subsoil fragipan that restricts drainage. All procedures were approved by the Ruakura Animal Ethics Committee, Hamilton, New Zealand (AE Application #2023) under the New Zealand Animal Welfare Act 1999.

Animal management and study design

Six groups (n = 72-75 cows each, 437 in total) were managed on a single farm, but two separate blocks, for the duration of the study. All cows were consuming their full winter diet prior to the start of the study, with transitioning onto fodder beet following recommended best practice (Gibbs 2014). Five groups were wintered on perennial ryegrass/white clover pasture paddocks supplemented with pasture baleage (Bal), and the sixth group grazed FB supplemented with pasture baleage. The Bal groups were split into two separate comparisons. The first, located on the support block, investigated the effect of baleage allocation frequency, a daily break shift (Bal_daily) or a 3-day break shift (Bal_3day) at the same 'daily' area allocation of 7.1 m^2/cow/day. The second, located on the milking platform, investigated the effect of daily area allocation, 6.7 (Bal_Sm), 7.5 (Bal_Med) and 8.6 (Bal_Lge) m^2/cow/day, with daily break shifts. Daily area allocation for the FB cows was on average 3.6 m^2/cow/day. Each treatment group remained in their allocated paddock throughout the trial period. The Bal_Lge group had access to shelter from a gorse hedge on the west side of their paddock for the first week of the study and the Bal_Sm for the first two weeks. No other treatment groups had access to shelter. Paddocks within each comparison were selected to be similar in soil type, pasture species, fertiliser history and topography but were not all adjacent to each other. All pasture paddocks had been in pasture for at least four years.

Cows were non-lactating and pregnant (mean ± SD; 74 ± 17 days prepartum) and groups were balanced for age (4.2 ± 2.2 yr), predicted calving date (25 Aug 24 ± 15.9 d) and pre-winter body condition score (BCS; 4.8 ± 0.49) on a 10-point scale (Roche et al. 2004).

Within each group, 30 mixed-age cows were randomly selected for behaviour monitoring, based on age, calving date and genetic merit, using a rear leg mounted IceQube activity meter (IceRobotics, Peacock Technologies, Edinburgh, Scotland). Any cows with recorded lameness from the 2023-24 season were excluded from the behaviour subgroup. The legs of behaviour-monitored cows were checked daily for signs of lameness, rubbing or irritation, and, if necessary, the IceQube was removed and reattached to the other leg. If a device came off in the first two weeks of the study, it was reattached or replaced with an alternative device. Any cows that lost their device from week 3 onwards did not receive a replacement.

Cow rumination behaviour was monitored in all cows using Allflex SenseHub® neck collars (MSD Animal Health 2026). The system uses collarmounted accelerometer sensors to generate proprietary indices of activity, rumination, and rest. No validation of the Allflex collars against visual rumination observations was completed under the conditions being tested in this study.

Body condition score was assessed for all cows on the 10 June, just prior to the start of the trial period, the 24th June and the 11 July, at the completion of the trial.

Daily management

Daily access to fresh feed (with exception of Bal_3day, which received a fresh area every fourth day) began at 07:00 h and took up to 2 hours, with the paddock order being changed daily to remove any bias associated with weather conditions e.g., frost, on paddock measurements. Each paddock contained a portable water trough always located close to the feeding face. Baleage groups were offered approximately 12 kg dry matter (DM)/cow/day of pasture baleage in round bale feeders. Pasture allocation was not standardised across the treatment groups, but was instead a function of the pre-graze mass and area allocation. The FB group was offered on average 8.7 kg DM/cow/day of fodder beet and 4.5 kg DM/cow/day of pasture baleage in round bale feeders. Cows on fodder beet were supplemented with 50 g dicalcium phosphate/cow/day (DCP, ≥18% P, ≥21% Ca, ≤0.18%) dusted onto baleage and 70 g/cow/day of a loose lick provided in troughs at the edge of

the break (Magphos lick, 11% P, 20% Mg, 6.4% Na) (Gibson et al. 2025).

All groups were back-fenced with the back fence of the daily allocation groups being moved up daily to keep the total area available consistent throughout the trial period. The area available was set to 3 days allocation of area for the baleage treatments and 5 days for the fodder beet. Additional baleage was offered (and recorded) at 15:00 h if a group had consumed all their daily baleage allocation.

Feed sampling

Fodder beet yields were measured fortnightly during the trial period as per the method of Wheadon et al. (2023), and the information was used to adjust daily allocations for more accurate feeding. Subsamples of leaf and bulb were collected for quality analysis. Samples of baleage were collected once per week for quality analysis by randomly grabbing handfuls of baleage from all bales in the daily allocation within each treatment group to generate one bulked sample per treatment group per week. Snip cuts of pasture from the area to be grazed over the next 7 days were also collected to estimated grazing height once per week. Feed samples were sent fresh to Hill Laboratories (Hamilton, NZ) where sample preparation and quality analysis was conducted as described by Wheadon et al. (2023).

Paddock management and measures

Pasture paddocks were closed in autumn with the intention of achieving 2800 kg DM/ha pre-graze cover at the start of the experiment. Bales were laid out in paddocks following their last grazing to achieve the daily area allocations of 6.7, 7.5 and 8.6 m^2/cow/day. These area allocations equated to approximately 18, 16 and 14 tonnes (t) baleage DM/ha, respectively, for the Bal_Sm, Bal_Med and Bal_Lge treatments (based on an estimated bale weight of 220 kg DM/bale). For the frequency comparison, the bales of baleage were laid out at the same density (17 t DM/ha), following a late cut of baleage, to provide 7.1 m^2/cow/day equivalent.

Once per week during the experiment the pasture area to be grazed over the next week was plated following a W pattern to estimate pre grazing pasture mass using a rising plate meter (Model EC09 Electronic Plate meter, Jenquip, Feilding, New Zealand) and converted to kg DM/ha using the winter equation (140*height+500).

Soil conditions in each paddock were scored daily for surface wetness, surface water pooling, and mud depth. These measures were intended to be simple and practical methods to assess paddock soil conditions. All scores were taken daily at 25 sites per paddock, sampled in a double-W pattern covering the length and width of the paddock, resulting in four transects along the length of the paddock (Neave et al. 2022). Sampling was avoided within 5 m of a bale feeder or the portable water trough. Paddock scoring always began at the same location on the double W in each paddock. Scores were taken starting at 09:00 h, regardless of weather conditions, and took approximately 30 minutes per paddock to complete. Teams of two completed the scoring each day and three people were on the roster. No inter-observer reliability was undertaken. For all except Bal_3day, the measurements occurred across the previous 3 days break but did not include the break that had just been allocated. For the Bal_3day paddock, the transect was located across the whole area that was available to the cows, i.e., measurements were done across the same area for three consecutive days. Further detail about each of the measurements is outlined below.

The surface wetness score at each of the 25 sampling sites (gumboot score) was assessed once per day using the boot score method. In brief, the researcher pressed their boot firmly into the soil at the site, removed their boot to leave a boot print, and then scored the appearance of the boot print as dry, wet, or sodden based on the criteria outlined by Neave et al. (2022).

Surface water pooling was assessed as any visible liquid (water or urine) pooling in close vicinity of the sampling site (within a half-boot length), and was scored as a binary outcome (Yes, No) should be this parenthesis., where "yes" indicated surface water pooling present. This score was taken once at each sampling site. Size of pooling needed to be at least the size of the palm of the hand to be scored as "yes".

Mud depth of the soil was measured using a standard 30-cm plastic ruler that was pushed into the soil by hand until it no longer moved, and depth was recorded in centimetres. This was repeated and recorded three times at each of the 25 measurement sites.

In the Bal_ paddocks, an assessment was made of the proportion of bare ground using a laminated quadrat sheet with 25 cells, each 5 cm × 5 cm. The quadrat was placed on the ground at each measurement site and the number of cells that were more than 50% bare ground were scored as 1, 50% bare ground as 0.5 and less than 50% bare ground as 0. Assessments were not made in the fodder beet paddock as all vegetation was removed during grazing resulting in 100% bare ground.

Weather measures

Rainfall (daily total, mm), soil moisture (daily average, mm), soil temperature (daily average, °C) and wind speed (daily average, km/h) were recorded daily from an onsite weather station (Halo Monitoring Systems, Aquacheck 4) and ambient air temperature (°C) was recorded from NIWA (2026) station 12444 located at Invercargill airport approximately 12 km away (straight line distance) from the farm.

Data handling, statistical and descriptive analyses

Collected data were organized in four categories: paddock measurements, animal behaviour, rumination and weather. Paddock measurements comprised of

the double-W-transect-samples of surface wetness/gumboot score (Dry, Wet, Sodden), surface water pooling (Yes, No) and mud depth (as a proxy for pugging damage, cm). The animal behaviour data set derived from IceQube devices contained hourly recording for individual cows for steps (n), total lying time (min), total standing time (min), duration of each lying bout and transitions (up or down; n; summarised by 15-minute intervals), whereas the dataset derived from Allflex SenseHub collars had recorded daily individual cow rumination (min). Weather variables included daily rainfall (mm), soil moisture (mm), average soil temperature (°C), average wind speed (km/h) and average ambient temperature (°C).

Raw data were checked for consistency and completeness then inspected for integrity and biological relevance. For longitudinal data (repeated measurements in time) extended sequences of consecutive negative values or missing data were not considered in the analysis. Statistical analyses and graphical outputs were performed using R software (version 4.5.2 Core Team. 2024, Vienna, Australia). Thirteen cows had less than 14 days of lying data due to losing their IceQube or being removed from the study due to lameness and their data were excluded from the analysis. Four of the original cows were replaced in the first 10 days of the study.

Continuous variables were first assessed by summary tables by mean and standard deviation, whereas categorical variables were assessed in contingency tables by counts and percentages. Pearsons's correlations (r), $\alpha = 0.05$, were utilised for paddock measurements, animal behaviour, and rumination, screening for collinearity and informing biological relevance. Weather measurements were plotted, visually inspected and utilised descriptively.

Effects of wintering systems were assessed using a linear mix-effect model (LMM) and generalized linear mix-effect model (GLMM) depending on data structure and the expected distribution (e.g., gaussian, binomial) of the predicted variable. For paddock measurements, nested transects sampled within paddock, and paddock itself, were treated as random effects (intercept) to account for hierarchical sampling. For behavioural and rumination datasets, repeated measures over time and individual cow-measurements were treated as crossed random effects (intercept) to account for independence. For LMM, paddock and animal behaviour variables were visually inspected for normality of residuals and homogeneity of variances through Q-Q plots and Levene's Test. The GLMMs were assessed using residual diagnostics appropriate to the distribution. Statistical significance was set at $\alpha = 0.05$ and post-hoc comparisons were conducted using Tukey's pairwise comparisons of marginal means using Satterthwaite p-value approximation for degrees of freedom. Pairwise comparisons were preferred instead of pre-specified contrasts due to trial design and absence of previously built hypotheses.

Results

The fodder beet crop averaged 22.8 t DM/ha and comprised 26% leaf and 74% bulb. There was a range in baleage quality but, on average, it contained 14% crude protein (CP) on a DM basis, 9.6 megajoules of metabolisable energy (MJME)/kg DM and was 43% DM (Table 1). Pre-graze pasture mass averaged 2594 ± 54 kg DM/ha across all the Bal treatments and based on the area allocation of the different treatments contributed approximately 1-1.2 kg DM/cow to daily DM intake. Estimated daily metabolisable energy and crude protein allocations were 128 MJ and 1516 g for Bal_Freq, 113 MJ and 1412 g for Bal_Area, and 170 MJ and 1762 g for FB, respectively.

While a wide range of weather conditions were recorded over the 30-day study period, the period was drier on average than the previous six years. Only 54 mm of rain fell from 11 June to 16 July 2024 compared with an average of 82 mm (53–122 mm) in the previous six years. However, autumn 2024 was wetter than average with 241 mm of rain recorded from 1 March to 31 May, compared with an average of 197 mm (range 140–270 mm) in the previous six years. While mean daily rainfall during the study period was 1.8 mm, the maximum recorded was 12.8 mm (Table 2) and rainfall occurred on 17 of the 30 days (Figure 1).

Table 1 Nutrient content (mean ± SD) of the forages and supplements fed during the 30-day study period (12 June - 11 July 2024).

Variable	Baleage	Fodder beet leaf	Fodder beet bulb	Pasture
Dry Matter (%)	43.3 ± 9.0	9.0 ± 0.7	17.0 ± 0.3	17.4 ± 1.7
Crude Protein (%DM)	14.0 ± 3.5	21.6 ± 1.6	10.9 ± 1.5	20.8 ± 1.3
Organic Matter Digestibility (%DM)	66.8 ± 8.1	88.6 ± 2.2	96.6 ± 0.4	80.1 ± 1.7
Metabolisable Energy (MJ/kg DM)	9.6 ± 1.1	11.9 ± 0.5	12.8 ± 0.1	11.5 ± 0.3
Neutral Detergent Fibre (%DM)	50.2 ± 5.7	27.1 ± 3.7	13.1 ± 1.1	44.3 ± 1.3
Acid Detergent Fibre (%DM)	29.9 ± 3.4	13.5 ± 1.8	7.8 ± 0.5	23.2 ± 0.7

Table 2 Average daily weather conditions and soil moisture recorded over the duration of the 30-day study period (12 June - 11 July 2024).

Variable	Mean	SD	Minimum	Maximum
Rainfall (mm)	1.8	3.2	0.0	12.8
Soil moisture (mm) [1]	36.5	0.34	36.0	37.0
Soil temperature (°C) [1]	8.1	0.54	7.2	9.2
Windspeed (km/h)	5.1	3.7	1.3	18.1
Ambient temperature (°C)	6.1	1.5	3.5	9.6

[1] Average of the four depths reported by the Halo Aquacheck 4 system (100, 200, 300 and 400 mm depths).

There were no significant differences in the mean percentage of the paddock scored as dry, wet or sodden between treatments (Table 3). On days when no rain was recorded, 50% of measurement sites were recorded as 'dry' compared with only 10% on days of rain and 3% on the day after rain (data not included). On the day of a rainfall event, 27% of sites were classified as sodden and 62% as wet (data not included).

Mud depth was lowest for Bal_3day and Bal_Lge paddocks and greatest for the FB (Table 3). For all treatments, mud depth increased on the day after rain from an average of 9 cm to 11.5 cm (data not included). Numerically, the percentage of bare ground was lowest in the Bal_3day treatment but not significantly so (Table 3). The proportion of the sites scored with surface pooling did not differ between treatment groups.

There was no significant difference in average lying time between the treatments ($P > 0.05$; Table 4), with groups averaging between 9.3 and 10.3 h/day across the 30-day experimental period. Individual cow average lying time ranged from 6 h/day to 13.9 h/day with similar variation in range across the treatment groups. Daily lying time for all treatments was significantly affected by rainfall, with daily means as low as 3 h/day being observed on days when more than 5 mm of rainfall were recorded (Figure 1). For all treatment groups, lying hours had recovered to pre-event levels within 24 hours of the rain event. There was a significant ($P < 0.05$) negative correlation ($r = -0.61$) between lying time and the proportion of the paddock with surface pooling, irrespective of treatment group.

Cows in all treatments were more likely to lie between 20:00 h and 07:00 h, with cows wintered on fodder beet lying less during daylight hours but more during the evening hours (Figure 2).

Cows in the Bal_Freq comparison (Bal_3day and Bal_daily) took fewer steps and thus walked less than those in the Bal_Area comparison (Bal_Sm, Bal_Med, Bal_Lge), while cows wintered on FB had intermediate scores relative to Bal_Freq and Bal_Area (Table 4). Within the Bal_Area comparison, cows in the Bal_Lge

Table 3 Soil conditions (mean (range) or mean ± SD) in wintering paddocks for cows offered baleage at two frequencies (Frequency) or three area allocations (Area) or fodder beet (Crop) measured daily, at 25 points within the daily allocated area, over the duration of the 30-day study period (12 Jun-11 July 2024).

	Wintering system	Daily area allocated and total available (m²/cow)	Baleage density (bales/ha)	Gumboot score			Mud depth (cm) [1]	Bare ground (%)[1]	Surface pooling present (%)
				Dry (%)[2]	Wet (%)[2]	Sodden (%)[2]			
Frequencyy	Bal_daily	7.1 (21.3)	76	43.0 (39.5–46.7)	50.1 (46.4–53.7)	6.9 (5.3–9.0)	8.9 ± 4.8[b]	93 ± 13.8	2.2
	Bal_3day	7.1 (21.3)	76	35.7 (32.2–39.3)	55.7 (52.0–59.3)	8.6 (6.8–10.9)	6.4 ± 4.7[a]	73 ± 32.6	3.0
Area	Bal_Sm	6.7(20.1)	80	34.3 (31.0–37.7)	55.1 (51.5–58.6)	10.7 (8.7–13.1)	7.3 ± 4.3[b]	93 ± 16.2	2.9
	Bal_Med	7.5 (22.5)	71	35.7 (32.4–39.2)	56.4 (52.8–59.9)	7.9 (6.2–10.0)	8.0 ± 4.4[b]	91 ± 16.4	2.5
	Bal_Lge	8.6 (25.8)	62	27.2 (24.1–30.5)	61.7 (58.2–65.1)	11.1 (9.0–13.5)	6.5 ± 3.8[a]	88 ± 18.6	2.9
Crop	FB	3.6 (18)	NA	27.2 (24.1–30.5)	56.8 (53.2–60.3)	16.0 (13.6–18.8)	14.2 ± 5.0[c]	NA	4.5

[1] Vertical letters for Mud Depth represent Tukey pairwise comparisons. Distinct letters account for different statistically significant groups ($P < 0.05$).
[2] Gumboot score ranges computed as binomial confidence intervals (95%).

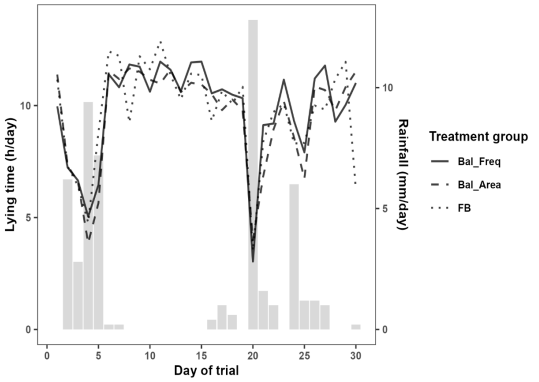


Figure 1 Daily rainfall (mm/day; grey bars) and average daily lying time (h/day; solid and dashed lines) of non-lactating dairy cows wintered on baleage (Bal) or fodder beet (FB n = 21-27 cows/day) at different frequencies of baleage allocation (Bal_Freq, n= 48-50 cows/day) or different area allocations (Bal_Area n = 86-88 cows/day) over the duration of the 30-day study period (12 June - 11 July 2024).

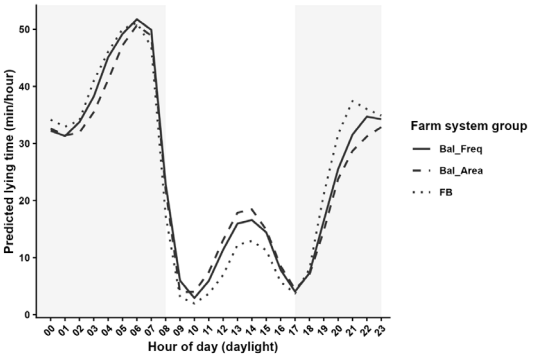


Figure 2 Diurnal lying time (min/hr) of non-lactating dairy cows wintered on baleage (Bal) or fodder beet (FB = 21) at different frequencies of baleage allocation (Bal_Freq n = 49) or different area allocations (Bal_Area = 89) over the duration of the 30-day study period (12 June - 11 July 2024). Hourly means based on 710-887 cow-hour observations per treatment group.

group had more transitions between lying and standing than the Bal_Sm group, while cows in the Bal_Med group had values similar to those observed for the Bal_Freq and FB cows.

Feed type i.e., Bal vs FB had a significant effect on rumination time (Table 4), as cows offered FB spent, on average, 152-180 fewer minutes ruminating each day than the other treatments. In addition to the lower average daily rumination time for cows on the FB treatment, there was a larger range between days, from a high of 650 min to a low of 240 min. A 3-day trend was observed in the daily rumination of the Bal_3day treatment, with rumination time lowest on the first day in their 3-day break, and highest on the second day, before declining to intermediate values on the third day (data not included). Within the baleage treatment groups only, the Bal_Med cows had a greater daily rumination time than Bal_Sm cows, but neither group differed relative to the Bal-Lge cows or the Bal_daily and Bal_3day cows (Table 4).

There was no difference in BCS gain between the treatment groups, which averaged between 5.2 and 5.3 BCS units on the 23 July 2024 (data not included).

Table 4 Adjusted marginal means and confidence interval's (95% CI) of behavioural and rumination variables for non-lactating dairy cows wintered on baleage (Bal) at two frequencies (Frequency) or three area allocations (Area) or fodder beet (Crop) over the duration of the 30-day study period (12 June - 11 July 2024).

	Wintering system	Lying time (h/day) [1]	Steps (n/day)	Transitions (n/day)	Rumination (min/day)
Frequency	Bal_daily	10.3 (9.9–10.7)	1405^{a} (1355–1455)	14.6^{ab} (14.1–15.1)	584^{ab} (571–597)
	Bal_3day	9.4 (9.0–9.8)	1320^{a} (1265–1375)	14.2^{ab} (13.7–14.7)	576^{ab} (563–589)
Area	Bal_Sm	9.6 (9.1–10.0)	1740^{b} (1660–1820)	12.4^{b} (11.9–12.9)	572^{b} (560–584)
	Bal_Med	9.3 (8.9–9.7)	1770^{b} (1700–1840)	14.3^{ab} (13.8–14.8)	600^{a} (588–612)
	Bal_Lge	9.7 (9.3–10.2)	1680^{b} (1610–1750)	15.1^{a} (14.6–15.6)	582^{ab} (571–594)
Crop	FB	9.5 (9.1–9.9)	1610^{ab} (1530–1690)	14.1^{ab} (13.6–14.6)	420^{c} (408–431)

[1] No statistical difference detected

Within columns, distinct letters account for different statistically significant treatment groups ($P < 0.05$).

Discussion

Dairy cows in southern regions of New Zealand have traditionally been wintered on fodder crops (kale, fodder beet, swedes) supplemented with pasture baleage (Edwards et al. 2017). However, in the last 5 years there has been increased adoption of baleage wintering as dairy farmers seek options that improve animal welfare and meet environmental expectations.

An observational study at the SDH investigated whether a range of baleage wintering systems could improve wintering conditions for cows by reducing soil damage and increasing lying time. Results should be interpreted in light of study design limitations: the baleage frequency treatments were on the adjacent support block, which differed in soil type and management history from the milking platform; the remaining baleage and fodder beet treatments were on the same soil type on the milking platform but not all adjacent and two treatments had access to shelter from a gorse hedge for the first 1 or 2 weeks of the study; treatment herds were balanced for age, calving date and body condition score, but not previous lactation management and there was no treatment replication.

The greater mud depth observed in the FB paddock was not surprising given the smaller daily area allocation per cow (3.6 m^2/day) compared with the Bal treatments that ranged from 6.7 to 8.6 m^2/day. In addition to the area difference, which is dictated by the crop yield and the proportion of the diet offered as FB, the FB paddock was cultivated during crop establishment and once the bulb had been eaten there was no vegetation to protect the soil structure. In contrast, the Bal treatment paddocks had been in permanent pasture for at least four years and the pre-graze pasture mass and associated roots likely provided protection from treading damage during winter grazing as demonstrated by Simon et al. (2024). Despite a higher-than-expected proportion of bare ground in the baleage treatments there was visual evidence of pasture remaining after grazing across the treatment area, however the amount visible was very much dependent on the weather conditions.

The least soil damage (based upon mud depth) was observed with Bal_Lge and Bal_3day treatments highlighting the impact of stocking density on soil conditions (Drewry and Paton 2000, 2005). In the Bal_3day treatment, the access to 3 days' worth of area, when a new break was offered, potentially reduced the competition among cows for space; however, this did not significantly alter the gumboot scores, surface pooling or % bare ground compared with the Bal_daily group. Forage crop wintering evolved in Southland to provide sufficient high-quality feed, minimising the area required for wintering and protecting soils and pastures from damage during winter. In the current experiment doubling the daily area allocation compared with fodder beet wintering did not lower the grazing pressure sufficiently to improve soil structural resilience and pasture cover. Simon et al. (2024) compared brassica wintering to pasture and baleage wintering on imperfectly drained soils with a high vulnerability to water logging in South Otago. Even at 13-16 m^2/cow/day area allocation recovery of pasture after winter grazing was slow, with 20-30% of the area remaining bare three months after winter grazing. Further research into baleage wintering is required to determine the optimal winter area allocation that minimises soil and pasture damage, supports pasture recovery, and balances the competing demand for land available for milk production, conservation or rearing replacements.

Unsurprisingly, mud depth was positively associated with rain events, with the biggest impact observed the day after rain. The increased frequency of wet and sodden gumboot scores following rain events greater than 5 mm suggests, unsurprisingly, that soil moisture content is an important driver of soil damage and mud depth. In addition, there was a significant negative relationship between surface pooling and lying time. The Bal_3day treatment had a numerically lower proportion of the paddock with bare ground, suggesting potential benefits to this wintering approach in protecting soil from damage. However, with the research only conducted on one soil type, future research is required to better understand the opportunities of this management on a range of soil types.

One of the drivers for farmers adopting baleage wintering is the premise that it provides better lying conditions for cows. However, our results do not support this, with no significant difference in lying time observed between treatment groups and average daily lying time ranging between 9.3 and 10.3 h/day. Schütz et al. (2024) compared lying behaviour of cows wintered on kale with those wintered on pasture and hay and reported similar lying times between treatments; namely 8.9 and 8.7 h/day, respectively. The effect of rain events on cow lying time in the current study was similar to that reported by Schutz et al. (2024), Neave et al. (2022) and Dalley et al. (2021) who observed reduced lying time on wet days with evidence of rebound lying once unfavourable weather conditions stopped. The proportion of the paddock with surface pooling was a key driver of reduced lying time on wet days for all treatments. Although rainfall during the experimental period was below the 6-year average, above-average autumn rainfall meant soils were already at, or near, field capacity at the start of winter, increasing their susceptibility to becoming sodden following relatively small rainfall events.

Transitions between lying and standing can be an indicator of cow comfort, with more, shorter lying bouts normally associated with poor lying conditions

(Dalley et al. 2012). In our study, the Bal_Lge treatment had the most transitions, a surprising result given this treatment had the least pugging (as indicated by mud depth) than other baleage treatments. The larger daily allocation area may have resulted in less competition for lying space (Fregonesi et al. 2007), so cows were more inclined to get up and move around knowing there would still be suitable spaces for their next lying bout.

The diurnal patterns in lying time were similar between the treatment groups with cows most likely to lie between 20:00 h and 07:00 h, when feeding commenced. There was a second, smaller period of lying between 13:00 h and 15:00 h. The early afternoon lying does not appear to be associated with time of fresh feed allocation as the proportion of cows lying during this time was similar between the Bal_daily and Bal_3day treatments. If cows are not observed lying during these periods farmers should assess ground conditions and implement contingency plans (DairyNZ 2024) to ensure cows are achieving sufficient lying time.

The absence of a difference in daily lying time between the Bal_daily and Bal_3day treatments was at odds with farm team observations. Interestingly, the farm team felt that the Bal_3day cows were more content and 'happier' than those in the Bal_daily treatment as they exhibited more playful behaviour i.e. bursts of running, jumping, and play-fighting (Bailly-Caumette et al. 2023) when being offered fresh feed and were more likely to be observed lying down when being checked.

One possible explanation for fewer steps in the Bal_Freq groups compared with the Bal_Area groups relates to the location of these treatments. The Bal_Freq groups were wintered on the support block, 1 km from the farm dairy (straight line distance), and thus were exposed to less farm vehicle traffic throughout the day compared to the Bal_Area cows who were wintered on the milking platform with four mobs wintering on fodder beet. Dairy cows are often seen to associate farm vehicle traffic with the provision of fresh feed; therefore, the greater number of vehicle movements on the milking platform is a potential cause of the increased walking observed in the Bal_Area treatments.

To our knowledge, this is the first study comparing daily rumination time of cows wintered on baleage to those wintered on fodder beet. The time a cow spends ruminating depends on the quality of feed and additional supplements consumed (Heublein et al. 2017; Iqbal et al. 2022). The nutritive characteristics of the feeds in this study were within the range reported by Woods et al. (2023). However, with significant differences in the quality and type of feed offered to treatments in this study, it is not surprising there were large differences in rumination time, with cows on the FB diet ruminating for approximately 2 hrs less each day.

The Bal treatment groups' diet contained, on average, approximately 50% neutral detergent fibre (NDF) (Table 1) compared with only 27% for the FB diet (based on proportion of FB (leaf + bulb) and baleage in the diet and their relative NDF contents). The average rumination minutes of 572–600 min/day for the Bal treatments were similar to the 598–692 min/day reported by Iqbal et al. (2022) for lactating cows in a rotational grazing system. Schütz et al. (2024) also reported increased rumination activity for cows wintered on pasture and hay compared with those wintered on crop (kale). In contrast, Fleming et al. (2021) reported higher rumination time (539 min/day) for lactating dairy cows consuming 5.8 kg DM fodder beet and 9.9 kg DM spring pasture compared with those consuming 16.2 kg DM of spring pasture (453 min/day).

As well as having 26–30% fewer average rumination minutes per day (430 min/day average), the FB cows in our study also had more day-to-day variation, ranging from a high of 550 to a low of 240 min/day. On further examination, daily rumination in the FB treatment appeared to be affected by the amount of baleage offered each day. The mob required 1.5 bales of baleage per day to achieve their daily DM allocation, which was planned as 2 bales one day and 1 bale the next. While this was achieved, on average, across the study period there were periods when only 1 bale was offered for several consecutive days as a response to reduced utilisation of the previous day's baleage and fodder beet allocation. It was during these periods that rumination rates declined, increasing again when baleage allocations were increased to 2 bales per day. When feeding fodder beet, it is important that the fibre source does not become the 'adjustable' part of the diet. Consistent baleage allocation is important to maintain rumination, support rumen health and reduce the risk of rumen upsets, especially when fodder beet makes up a high proportion of the diet.

Differences in rumination time can affect saliva secretion that helps stabilise ruminal pH by buffering the organic acids produced during the fermentation of carbohydrates (Beauchemin 2018). Jonker et al. (2022) reported that diets with >60% fodder beet supplied insufficient physical NDF to meet nutritional requirements. On days when only 1 bale was offered, the diet comprised more than 60% fodder beet. While there were no signs of clinical ruminal acidosis, it is plausible that some animals were experiencing subclinical ruminal acidosis during these periods of low rumination activity. Antanaitis et al. (2024) reported that cows with subclinical acidosis had a 6.6% decrease in rumination time, with an average daily rumination time of 488 ± 32 min/day, significantly greater than

the low of 240 min/day observed on some days in the current study and greater than the average of 430 min/day.

Conclusions

For the slowly permeable soils used in this study and the space allowances ranging from 6.7 to 8.6 m^2/cow/day our results do not support the premise that baleage wintering provides better lying conditions for cows than wintering on fodder beet. Similar mean daily lying times were observed across all treatments and cows in all treatments had reduced lying on wet days, consistent with negative relationships between lying time and surface water pooling. The least soil damage (based upon mud depth measures) observed with Bal_Lge and Bal_3day treatments highlights the impact of stocking density on soil conditions. Of concern is the greater variation in rumination times observed among cows wintered on FB. Further research is required to determine the implications of this variability for animal health and subsequent production.

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