

Grazing, Rumination, and Idling Behavioural Dynamics in Pasture Grazing Spring-Calved Dairy Cows: Whole Lactation Analysis

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Abstract

Background

This study examined variation in patterns and time budgets of grazing, rumination, and idling behaviours over the whole lactation season in New Zealand grazing dairy cows, focusing on the effects of breed, lactation age (2nd, 3rd, 4th), lactation stages (early, mid, late), and feed. The study considered hourly behaviour patterns (min/h spent on specific behaviour), daily time budgets (number of hours spent on each behaviour over 24 hours), lactation stage time budgets (number of hours spent on specific behaviour during early, mid, and late lactations), and lactation period time budgets (number of hours spent on specific behaviour during the lactation period). The study included a total of 108 spring-calved, multiparous Holstein-Friesian (HFR), Jersey (JE), and Holstein-Friesian Jersey Crossbreed (XB) dairy cows managed under rotational grazing and once-a-day milking (at 5:00 am) systems. The cows primarily grazed a mixed pasture of perennial ryegrass and clovers, with supplementary seasonal feed (silage, tapioca, turnips). Using the automated AfiCollar device, grazing and rumination behaviour (min/h) data for each individual animal were collected over two complete lactation periods. Idling behaviour (min/h) was calculated as the time not spent grazing or ruminating. The data were analysed using a repeated-measures analysis (PROC MIXED) in SAS.

Results

Cows grazed mainly during the daytime, with peaks at dawn and dusk, and spent the nighttime mostly ruminating. Jersey cows spent slightly more time grazing compared to others. The lactation stage mainly influenced grazing patterns, with cows grazing less and idling more when fed additional supplements. Hourly behaviour patterns and grazing and rumination daily time budgets varied significantly among breeds and lactation stages. Lactation stage time budget (LSTB) for grazing rumination and idling varied across early, mid, and late stages, but it remained almost similar between lactation age and breed. Lactation period time budget (LPTB) for grazing and rumination only varied among study years, whereas LPTB for idling varied among breeds as well.

Conclusion

Environmental conditions exert the strongest influence on cumulative grazing, rumination, and idling behaviours. Breed contributes to variation in idling behaviour, whereas lactation age has minimal effect once cows reach maturity. These findings offer insights into improving on-farm pasture management and animal welfare by addressing the behavioural needs.

1. Background

In New Zealand, the dairy production system is grazing-based and mainly relies on pasture of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) to meet the animals' nutritional requirements. The system has a favourable climate, which allows for year-round pasture production while reducing the need for supplementary feeds. Cows mainly graze on pasture and receive supplementary feeds only if required (Macdonald et al., 2008).

Grazing behaviour in dairy cows is a complex activity; it is mainly driven by their nutritional needs as well as the circadian rhythms (Rook & Huckle, 1995). Dairy cows typically exhibit diurnal grazing patterns, with intense grazing peaks around early morning and late afternoon, with three to five daily grazing events. Grazing activity patterns are influenced by numerous factors, such as the nutritional requirements of the animal, availability and quality of pasture, sward structure, and environmental conditions (Gregorini, 2012). After grazing, rumination is another important activity performed by dairy cows. Rumination plays a vital role in the digestion and utilization of fibrous feed, and this behaviour is considered a critical indicator of animal physiology. Rumination activity is typically higher when cows are resting, and highest from late night to early morning (Schirrmann et al., 2009). This pattern optimizes efficiency in the digestion process, as ruminating while lying down enhances saliva production and buffering of rumen acids (Welch, 1982). In general, cows allocate 7 to 10 hours to perform rumination, with variations influenced by diet composition, lactation stage, and health status (Schirrmann et al., 2012).

Dairy cows undergo physiological changes throughout their lactation period, which can directly affect their grazing, rumination, and idling behaviours. Cows' changing metabolic demands at different stages of lactation are reflected in the variations in duration and intensity of grazing sessions (Bargo et al., 2003). For instance, during early lactation, cows are often fed high-energy diets to support the onset of milk production, which potentially leads to high rumination activity (Krause & Oetzel, 2006). Therefore, cows have high metabolic demands during the early lactation phase. Mid-lactation is a more stable phase, in which cows achieve a balance between energy intake and milk yield. However, in mid- and late lactation, rumination activity generally stabilizes as the cows' diet balances out and their metabolic demands are moderate (DeVries et al., 2003). However, milk production declines as cows transition into late lactation, and their nutritional requirements also decrease. They may spend less time grazing towards the end of lactation as their energy needs decrease (Grummer, 1995; Bach et al., 2009; Kennedy et al., 2009).

Changes in grazing behaviour could be an indicator of variations in pasture quality or availability; this signal allows farmers to make timely management decisions, for example, adjusting stocking rates or supplementing feed (Rutter, 2010). Therefore, understanding grazing activity is essential for optimizing pasture management strategies to ensure that cows meet their nutritional needs effectively, which can improve health, productivity, and animal welfare (Chapman et al., 2007). Similarly, changes in rumination behaviour could be an early sign of any metabolic disorders, gastrointestinal disturbances, or other health-related issues (Soriani et al., 2012), allowing farmers to take precautionary measures. Thus, by

monitoring these behaviours, farmers can gain insight into animals' behavioural adaptations to the varying physiological demands of their specific lactation.

Although these behaviours are very important, there is limited data on how grazing, rumination, and idling patterns and time budgets change during different stages of the lactation cycle. Previous studies have explored different aspects of cattle behaviour, while studies considering the full lactation period are lacking for grazing-based systems. This is because monitoring these behaviours has been a challenge. However, advancements in precision dairy farming technologies, such as automated behaviour monitoring tools, have made it easier to track these behaviours accurately and in real-time (Borchers et al., 2016; Iqbal et al., 2021). This study aimed to fill these gaps by providing a detailed analysis of the grazing, rumination, and idling behaviour patterns and time budgets of dairy cows during early, mid, and late lactation stages as well as the complete lactation period.

2. Materials and Methods

2.1. Study Area

The study was carried out at Dairy Unit 1, Massey University, Palmerston North, New Zealand (Latitude: -41.3009, Longitude: 174.7720). The area has a temperate climate, which is classified into four seasons: spring (September to November), summer (December to February), autumn (March to May), and winter (June to August). During the study period, the local average annual temperature was around 14°C, precipitation was around 970 mm, sunshine hours were 1735, and relative humidity was 81% (NIWA, 2020).

2.2. Animal Model

As shown in Fig. 1, this research involved multiparous, spring-calved, lactating dairy cows ($n = 108$) with a study group of 54 cows, randomly selected each year from the larger herd ($n = \sim 260$). The study group in each year consisted of 18 cows from each of three breeds, including Holstein-Friesian (HF), Jersey (JR), and Holstein-Friesian/Jersey Crossbreed (XB). Those 18 cows within each breed belonged to different lactation ages, six cows ($n = 6$) from each of the 2nd, 3rd, and 4th lactations with varying breeding worth ($103 < \text{BWI} < 151$). Breeding Worth (BWI) index value is a measure of the genetic merit of an animal for farm profitability (Al-Marashdeh et al., 2020).

2.3. Animal Management and Study Period

The cows were housed in grazing paddocks at dairy unit 1 throughout their lactation period. Dairy Unit 1 is a pasture-based dairy farm following spring calving, rotational grazing, and once-daily milking (at 5:00 AM) operation. As shown in Table 1, study cows were kept mainly on grazing pasture consisting of perennial ryegrass (*Lolium perenne*) mixed with red clover (*Trifolium pretense*), white clover (*Trifolium repens*), and chicory (*Cichorium intybus*). The cows received supplementary feeds, including maize silage (*Zea mays*), corn gluten (*Zea mays* L.), tapioca (*Manihot esculenta*), turnips (*Brassica rapa*), and

distilled dried grains during different seasons. Distilled dried grains (pallets), corn gluten (pallets), and tapioca (ground meal) were offered in the milking shed, soon after milking. Maize silage and turnips were fed around midday while animals were in the grazing paddock. The cows had ad libitum access to drinking water.

Table 1
Feeds received by the experimental cows during the spring, summer, and autumn seasons for Year-1 and Year-2.

Lactation Stage	Feeds Consumed	
	Year-1	Year-2
Early	Pasture, Chicory	Pasture, Chicory
Mid	Pasture, Turnips, MS	Pasture, Turnips, MS
Late	Pasture, DDG, Tapioca	Pasture, DDG, Tapioca

* Year-1 and Year-2 represent the lactation span for 2019-20 and 2020-21, respectively.

* DDG = Dried distilled grain, MS = Maize silage.

This research study took place over two years and covered two complete lactation periods (2019-20 and 2020-21). The lactation period for dairy cows ranged from August to April of the following year (~ 270 days), aligned with the standard New Zealand spring calving system. Grazing and rumination behaviour data were collected from the onset of milking until the start of the drying period.

2.4. Automated Behaviour Recording

AfiCollar (Afimilk Ltd., Kibbutz Afikim, 1514800, Israel) continuously tracked minute-by-minute behaviours (grazing and ruminating) of the study cows on a real-time basis throughout the lactation period (Iqbal et al., 2021). The device had a triaxial (x, y, and z) accelerometer sensor kept in a box attached to the collar and positioned on the right side of the cow's neck. This sensor could recognize and classify specific behaviour categories (e.g., grazing and rumination) based on the patterns of the animal's head movements. The collected data were processed by the collar device using built-in generic algorithms and produced as minutes spent with hour (min/h) on specific behaviour. Idling behaviour was added as a new variable, which was calculated as the time (min/h) when the animal was neither engaged in grazing nor rumination (Forbes, 1988). Data were wirelessly (Wi-Fi) transmitted and stored in the base station computer when cows were within its range (~ 500 meters). Subsequently, the data were manually downloaded into a Microsoft Excel spreadsheet.

2.5. Data Preparation and Analysis

Grazing time and rumination time for the individual animal for each year were separately sorted in Microsoft Excel spreadsheets. The data collected were classified and sorted by study year (Year-1 and Year-2), breed group (HF, JR, XB), lactation age (2nd, 3rd, 4th), lactation stage (early, mid, late), and

feeding regimens within each lactation stage. Data analysis involved four levels: hourly behaviour patterns (min/h), daily time budgets (hrs/day or 24 hours), lactation stage (LS) time budgets (hrs/LS), and lactation period (LP) time budgets (hrs/LP) for grazing, rumination, and idling behaviours. Lactation stage time budgets and whole lactation time budgets were manually calculated for each animal using minute-per-hour grazing, rumination, and idling behaviour data. All analyses were performed in SAS (version 9.4, SAS Institute Inc., Cary, NC) using a mixed repeated measures design (PROC MIXED).

2.6. Behaviour Patterns

The model investigated differences in grazing, rumination, and idling behaviour (min/h) as described by (Jochims et al., 2020) and (Iqbal et al., 2023). Effects of year, breed, lactation age (LA), breed × LA (with three levels each), individual cow within breed and LA, time of the day, lactation stage (LS), day within LS, and their interactions. The main dependent variables were grazing, rumination, and idling time. Year, breed, lactation age, and lactation stage of the cows were included as the main fixed effects, while individual cow within breed and lactation age was treated as a random effect, and hour of the day was included as repeated measures on the subject cow. To determine hourly patterns, data were summarized and expressed as the least squares means of minutes spent grazing and ruminating within each hour over 24 hours.

2.7. Behaviour time budgets

Daily time budget (hrs/day or 24 hours), lactation stage time budget (LSTB, hrs/LS), and lactation period time budgets (LPTB, hrs/LP) for grazing, rumination, and idling were evaluated considering the effects of year, breed, lactation age, lactation stage, and their interactions.

3. Results

3.1. Behaviour Patterns

Year had significant effects on grazing and idling but not on rumination hourly patterns (Table 2). Breed had a strong effect on grazing and rumination, though it did not impact idling. Time of the day was highly significant across all behaviours, as was the lactation stage (LS). Lactation Age (LA) did not affect any of the behaviours. Statistical interactions among the study factors also showed effects on behaviour patterns; time of the day and LS showed significant interactions with year, breed, and lactation age for all behaviours.

Table 2
P values for the effects of year, breed, hour, lactation age, lactation stage, feed within the lactation stage, and their interactions on grazing (min/h), rumination (min/h), and idling (min/h) behaviours.

Effect	P Value		
	Grazing	Rumination	Idling
Year	0.0165	0.6293	0.0084
Breed	0.0015	0.0001	0.1567
Hour	< .0001	< .0001	< .0001
Feed (LS)	< .0001	< .0001	< .0001
Lactation age (LA)	0.575	0.4229	0.1169
Lactation Stage (LS)	< .0001	< .0001	< .0001
Year*Breed	0.0369	0.249	0.687
Year*LA	0.8602	0.7657	0.82
Breed*LA	0.8616	0.4875	0.9664
Hour*Year	< .0001	< .0001	< .0001
Hour*Breed	< .0001	< .0001	< .0001
Hour*LA	< .0001	< .0001	< .0001
Hour*LS	< .0001	< .0001	< .0001
Year*LS	< .0001	< .0001	< .0001
Breed*LS	0.0007	< .0001	< .0001
LA*LS	0.1344	< .0001	< .0001

(The significance level for the P-value was set at 0.05. * Indicates interaction between two effects.

The 24-hour patterns of grazing and rumination activities are presented in Fig. 2. Generally, all cows were predominantly engaged in grazing activity during daylight hours, while rumination remained the nocturnal activity. Grazing commenced in the early morning and continued throughout the day, with peaks after sunrise and before sunset, followed by a gradual decline in the evening. Grazing activity was highest in the morning and the late afternoon. Nighttime grazing was minimal, except for a short peak around midnight. In contrast, rumination activity was comparatively lower during the daytime. Rumination gradually rose in the late evening and remained high throughout the night. Rumination gradually decreased in the morning until cows were taken to the milking parlour.

The temporal distribution of grazing and ruminating behaviours across 24 hours exhibited large variations at the different stages of lactation (Fig. 3). The behavioural patterns corresponded to the seasonal changes in day and night lengths. During early and mid-lactation, grazing commenced and ended earlier (~ 6:00 PM) as the days were shorter. Whereas, during late lactation, grazing extended approximately two hours longer into the evening (up to ~ 8 PM). In addition, during the late lactation, grazing started early with a sharp increase in the early morning, and its intensity was greater. Daytime rumination activity was slightly higher during early lactation compared to mid and late lactations.

The 24-hour temporal grazing and rumination patterns over 24 hours were similar among cows of different lactation ages. The behaviour patterns were similar across HF, JR, and XB cows as well, with only slight variations. Jersey cows tended to graze for longer durations and displayed more consistent grazing activity compared to HF and XB cows. Additionally, the grazing activity for JR cows in the evening declined almost one hour later than that for HF and XB cows. Holstein-Friesian cows, however, exhibited a minor increase in rumination activity following their morning grazing peak.

3.2. Behaviour Time Budgets

3.2.1. Daily Time Budgets (DTB)

The results for grazing, rumination, and idling daily time budgets are shown in Table 3. Breed significantly influenced all behaviours' daily time budgets. As shown in Fig. 4, grazing DTB in JR (48%) was slightly higher than those of HF (45%) and XB (46%). Rumination time budget for HF (29%) was higher than that of JR (25%) and XB (26%). Grazing, rumination, and idling DTB were similar across different lactation ages; there was a trend of a slight increase in the idling DTB and a decrease in the grazing DTB with advancing lactation age (Fig. 5). Rumination DTB in 2nd lactation cows was slightly higher than that of 3rd and 4th lactation cows. In addition, there was significant interaction between Breed and LA for grazing, rumination, and idling DTBs.

Table 3

P values for the effects of year breed, lactation age, lactation stage, day within lactation stage, feed within the lactation stage, and their interactions on grazing, rumination, and idling time budgets (DTB, hours/day).

Effect	P Value		
	Grazing	Rumination	Idling
Year	0.073	0.5005	0.401
Breed	0.0003	< .0001	0.0406
Lactation Age (LA)	0.2423	0.025	0.0999
Lactation Stage (LS)	< .0001	< .0001	< .0001
Day (LS)	< .0001	< .0001	< .0001
Feed	< .0001	< .0001	< .0001
Year*Breed	< .0001	0.0033	0.6813
Year*LA	0.8461	0.5735	0.9503
Breed*LA	< .0001	0.0012	< .0001
Year*LS	< .0001	< .0001	< .0001
Breed*LS	< .0001	0.0003	< .0001
LA*LS	< .0001	0.0052	0.1112

Note: The significance level for the P-value was set at 0.05. * Indicates interaction between two effects.

The effects of LS and Day within LS were highly significant across all grazing, rumination, and idling daily time budgets. The DTB for grazing, rumination, and idling behaviours during different lactation stages greatly varied (Fig. 6). The grazing time budget followed a bell-shaped curve from early to late lactation cows. Rumination DTB in late (24%) lactation cows was significantly different from that of early (29%) and mid (28%) lactation cows. The proportion of the day spent idling was highest in late (32%) lactation cows, and similar in both early and mid-lactation cows (25%). In addition, there were significant interactions including Breed*LS and Year*LS for grazing, rumination, and idling DTBs. The overall daily time budgets for grazing, ruminating, and idling were similar in different study years. Irrespective of breed group, lactation age, and lactation stage, cows spent most of their time grazing, followed by ruminating and idling.

3.2.2. Lactation Stage Time Budget (LSTB)

The data shown in Table 4 reveals that lactation stage behavioural time budgets (hrs/LS) were mainly affected by the stage of lactation itself and the study year, while breed had a more specific influence, and

lactation age had minimal effect. Overall, cows in Year 1 spent considerably more time grazing (1007 hrs/LS) and ruminating (621 hrs/LS) compared with Year 2 (840 and 522 hrs/LS, respectively) and also showed greater idling time. The lactation stage had the strongest and most consistent effect on all behaviours' LSTBs. Grazing time was highest in early lactation (1260 hrs/LS), declined in mid-lactation (913 hrs/LS), and was lowest in late lactation (597 hrs/LS). In contrast, rumination peaked in mid-lactation (789 hrs/LS), while early lactation showed the lowest rumination (350 hrs/LS). Idling time was also greatest in mid-lactation. The Year $\times$ Lactation Stage interaction was highly significant for all behaviours, while the Breed $\times$ Lactation Stage interaction was significant only for rumination and idling.

Table 4

LSMeans, standard errors, and P values for the effects of year, breed, lactation age, lactation stage, and feed within the lactation stage, and their interactions on grazing, rumination, and idling lactation stage time budgets (LSTB, hours/lactation stage).

Effect	P Value					
	Grazing (hr/lb)		Rumination (hr/lb)		Idling (hr/lb)	
Year	< .0001		< .0001		0.001	
Breed	0.1888		0.1421		0.0061	
Year*Breed	0.4439		0.1804		0.5344	
Lactation Age (LA)	0.8263		0.9571		0.3473	
Year*LA	0.4874		0.5296		0.3521	
Breed*LA	0.8124		0.8435		0.888	
Lactation Stage (LS)	< .0001		< .0001		< .0001	
Year*LS	< .0001		< .0001		< .0001	
Breed*LS	0.0712		0.0298		0.0028	
LA*LS	0.2003		0.116		0.056	
Breed*LA*LS	0.6232		0.6952		0.5275	
Year	LSMean	SEM	LSMean	SEM	LSMean	SEM
1	1007	40.8	621	25.9	550	21.4
2	840	34.1	522	21.6	500	17.6
Breed						
HFR	848	47.3	553	30.0	471	24.7
JE	947	49.1	542	31.2	524	25.6
XB	975	41.1	619	26.1	581	21.4
Lactation Age (LA)						
2nd	940	42.9	577	27.2	507	22.3
3rd	915	43.5	567	27.6	543	22.7
4th	915	50.9	570	32.2	526	26.5
Lactation Stage (LS)						
Note: The significance level for the P-value was set at 0.05. * Indicates interaction between two effects. The hr/lb show number of hours spent on each behaviour over the lactation stage.						

Effect	P Value					
	Grazing (hr/lb)		Rumination (hr/lb)		Idling (hr/lb)	
Early	1260	29.5	350	19.7	437	17.9
Mid	913	30.0	789	18.8	682	16.7
Late	597	31.0	575	19.1	456	17.1
Note: The significance level for the P-value was set at 0.05. * Indicates interaction between two effects. The hr/lb show number of hours spent on each behaviour over the lactation stage.						

Breed did not significantly influence grazing and rumination LSTBs; however, it had a significant effect on idling LSTB. The Breed × Lactation Stage interaction was significant for rumination and idling LSTBs, indicating that behavioural differences between breeds became more pronounced at specific stages of lactation. Lactation age (2nd, 3rd, and 4th) did not significantly influence grazing, rumination, and idling LSTBs, and no meaningful interactions with other factors were detected.

3.2.3. Lactation Period Time Budget (LPTB)

As shown in Table 5, study year had a significant impact on all behavioural lactation period time budgets. Cows in the second year allocated more time to all activities compared to the first year, with grazing increasing from 2138.2 to 2511.8 hrs/LP, rumination rising from 1302.1 to 1559.8 hrs/LP, and idling growing from 1186.6 to 1496.3 hrs/LP. Breed did not have a significant impact on grazing or rumination LPTBs, although a trend was noted for rumination. Nonetheless, breed had a significant effect on idling time. XB cows recorded the highest idling time (1479.4 hrs/LP), followed by JR cows (1340.3 hrs/LP), while HF cows had the lowest (1204.7 hrs/LP). Lactation age did not significantly influence grazing, rumination, or idling LPTBs. None of the interactions, such as year × breed, year*LA, breed*LA, or year*breed*LA, had a significant impact on grazing, rumination, or idling LPTBs.

Table 5

LSMeans, standard errors, and P values for the effects of year, breed, lactation age (LA), and their interactions on grazing, rumination, and idling lactation period time budgets (LPTB, hours/lactation period).

Effect	P Value					
	Grazing (hr/lp)		Rumination (hr/lp)		Idling (hr/lp)	
Year	0.0017		0.0009		0.0001	
Breed	0.1357		0.0674		0.0054	
Year*Breed	0.4926		0.2214		0.7825	
Lactation Age (LA)	0.2773		0.5362		0.5174	
Year*LA	0.4447		0.5958		0.2702	
Breed*LA	0.9341		0.9499		0.896	
Year*Breed*LA	0.4291		0.4727		0.5765	
Year	LSMean	SEM	LSMean	SEM	LSMean	SEM
1	2138.2	84.93	1302.1	54.79	1186.6	56.71
2	2511.8	69.36	1559.8	44.75	1496.3	46.31
Breed						
HFR	2164.3	98.35	1412.8	63.45	1204.7	65.67
JE	2381.0	101.92	1349.4	65.75	1340.3	68.06
XB	2429.7	83.64	1530.7	53.96	1479.4	55.85
Lactation Age (LA)						
2nd	2403.6	87.15	1468.9	56.22	1311.6	58.19
3rd	2323.0	87.45	1424.5	56.41	1388.1	58.39
4th	2248.5	108.69	1399.5	70.12	1324.7	72.58
Note: The significance level for the P-value was set at 0.05. * Indicates interaction between two effects. The hr/lp show number of hours spent on each behaviour over the lactation period.						

4. Discussions

This study investigated the temporal patterns and time budgets of grazing, rumination, and idling behaviours in grazing dairy cows, utilizing a dataset collected throughout the lactation period with automated collars (AfiCollar). All cows were managed in a single herd on the same pasture; however, the study noted confounding effects of seasonal climate and supplementary feeding, as the two were closely linked, which may have influenced the findings.

Results showed that grazing predominantly occurred during daylight hours, with peak activity in the early morning and late afternoon, likely due to cooler temperatures and more favourable environmental conditions. This is consistent with the findings from previous research, which indicated that cows tend to graze more intensively during cooler parts of the day to avoid heat stress and maximize nutrient intake when forage quality is optimal (Rutter, 2010; Gregorini, 2012). The short peak in grazing activity around midnight suggests some opportunistic feeding behaviour, potentially driven by hunger or slight variations in environmental conditions such as nighttime temperature or moonlight (Leliveld et al., 2022). However, this nighttime grazing remains minimal, consistent with previous reports showing that dairy cows are diurnal grazers (Gregorini et al., 2006). In contrast, rumination was mainly performed during nocturnal hours, supported by earlier research showing that cows primarily ruminate when at rest, following periods of intensive grazing (Bargo et al., 2003; Beauchemin, 2018). The nocturnal rumination allows cows to efficiently digest and ferment forage consumed during the day, which is critical for nutrient absorption and overall health (Beauchemin, 2018). The decrease in rumination during the morning, particularly when cows are brought to the milking parlour, may also indicate that management activities influence the natural rumination cycle (Schirrmann et al., 2012). By aligning grazing management strategies, such as timing pasture access or feed supplementation, with cows' natural activity cycles, farmers can enhance forage utilization and potentially improve animal performance (Mattiada et al., 2013). Further research should investigate the effects of varying environmental factors and management interventions on these behavioural rhythms.

The 24-hour grazing and rumination patterns observed among JR, HF, and XB cows reflected important insights into breed-specific behavioural adaptations to pasture-based systems. Jersey cows displayed slightly longer and more consistent grazing activity, extending their evening grazing period compared to HF and XB cows. This suggests that JR cows may be better adapted to maximizing intake from grazing, which could be due to their smaller size and greater feed efficiency under grazing conditions, as previously noted (Bargo et al., 2003). The extended evening grazing in JR cows may also indicate that this breed prioritizes longer periods of energy intake in preparation for nighttime rumination. On the other hand, HF cows exhibited a noticeable increase in rumination following the morning grazing peak. This could indicate that HF cows, being larger in size, may require more time to process the forage they consume, aligning with previous findings suggesting that Holstein cows exhibit greater rumination activity to cope with higher dry matter intake demands (Kolver & Muller, 1998). The timing of this increased rumination suggests that HF cows may partition their digestion differently, potentially linked to the need to maximize the efficiency of nutrient absorption over a more condensed grazing period. The slight behavioural differences observed among breeds highlight the importance of considering breed-specific patterns when designing grazing and feeding strategies to optimize productivity and welfare (Pulido & Leaver, 2003). Future research could focus on how these behavioural differences impact overall production efficiency and whether management strategies should be tailored to different breeds to better align with their natural grazing and rumination rhythms.

The temporal grazing and rumination patterns observed over 24 hours showed no variations among cows during different lactation ages. This suggests that the lactation age does not alter the inherent

circadian feeding and digestive behaviour of dairy cows under pasture-based systems. These findings align with earlier studies, which have shown that the lactation age has minimal impact on the temporal distribution of grazing and rumination activities, with cows generally following similar diurnal patterns regardless of their lactational (Rook et al., 1994; Gregorini, 2012). These results imply that nutritional management strategies based on the activity patterns for grazing and rumination can be applied uniformly across cows at different lactation ages without the need for significant adjustments to accommodate changes in behaviour. Further investigation could explore whether specific nutritional or metabolic demands during different lactation ages may affect the efficiency of forage utilization or milk production, despite similar behaviour patterns.

The temporal distribution of grazing and rumination behaviours over 24 hours varied significantly across the different stages of lactation, closely aligned with the seasonal changes in daylight hours. During late lactation, shorter daylight hours resulted in an earlier start and end of grazing activity. In contrast, during the early and mid-stages of lactation, cows extended their grazing time by approximately two additional hours. This shift suggests that cows in early and mid-lactation adjust their feeding behaviour to maximize intake, reflecting an adaptive response to meet their energy. Interestingly, the grazing intensity during late lactation was more pronounced, particularly in the early morning, suggesting that cows may compensate for shorter days by increasing their grazing rate. This early-morning peak could indicate a strategy to maximize nutrient intake before the day's hotter period or other environmental factors causing a reduction in grazing activity. These findings are consistent with previous research that demonstrates how grazing patterns are influenced by both physiological needs and environmental cues such as day length and temperature (Rook & Penning, 1991; Gregorini, 2012). Rumination patterns also showed subtle differences across lactation stages. Daytime rumination was slightly higher during early lactation compared to mid- and late lactation, potentially reflecting the need for more efficient feed processing as cows require more nutrients during the high-demand phase of early lactation. However, despite these variations, the overall structure of rumination largely followed grazing, with higher activity during the night. These results emphasize the importance of understanding the interaction between the lactation stage and seasonal environmental factors when developing feeding and grazing management strategies. Adjusting feeding schedules and pasture availability to account for these behavioural shifts could help optimize nutrient intake and support better overall productivity throughout the lactation cycle.

The 24-hour time budgets for grazing, ruminating, and idling remained consistent across different years of the experimental period. Across all breed groups, lactation ages, lactation stages, and feed types, cows allocated the majority of their daily time to grazing, followed by ruminating and, lastly, idling. The stability of these behaviours over time aligns with established patterns in dairy cows, where grazing takes priority to ensure adequate intake, while rumination and idling follow predictable rhythms largely governed by digestion and rest requirements (Pérez-Ramírez et al., 2009; Gregorini et al., 2017). These findings highlight the importance of optimizing pasture access and feed availability to support cows' natural time allocation, which may ultimately enhance their productivity and well-being.

The analysis of daily time budgets for grazing, rumination, and idling behaviours further revealed significant effects of other factors. Breed showed a strong influence on grazing and rumination daily time budgets, suggesting that inherent genetic traits may contribute to variations in these activities. Jersey cows allocated a slightly higher proportion of time to grazing compared to HF and XB cows, respectively, which indicates that JE cows may have higher energy demands or distinct foraging patterns; this is consistent with other research suggesting breed-specific grazing strategies (Gregorini et al., 2017). In contrast, HF cows had a higher rumination time budget than JR and XB cows, reflecting potential breed differences in digestion and cud-chewing requirements, possibly due to variations in body size and intake rates (Bargo et al., 2003). Interestingly, idling time was relatively uniform across all breeds, suggesting that idle behaviour may be less influenced by breed-related factors and more regulated by intrinsic rest and recovery needs. Moreover, lactation age affected the rumination DTB, implying that as cows age, their rumination patterns are likely adjusted to meet changing digestive efficiency and metabolic needs. However, the trend showing an increase in idling time and a decrease in grazing time with advancing lactation is noteworthy. This shift may reflect physiological changes that affect energy demands and behavioural priorities as cows age. The increased idling time may suggest a compensatory behaviour in response to reduced grazing time, possibly as a strategy to manage energy balance and maintain body condition (Ingvarsen & Moyes, 2013). Future studies should aim to elucidate the underlying physiological mechanisms driving these changes and their implications for herd management practices.

The significant effect of LS on grazing, rumination, and idling DTBs emphasized the importance of lactation status in shaping cows' feeding and resting behaviours. This finding is consistent with previous studies showing that cows' physiological demands vary across lactation stages, influencing their time allocation for different activities (Delagarde et al., 2001). The grazing DTB with peaks in early and mid-lactation followed by a decline in late lactation is consistent with previous research suggesting that energy requirements and nutritional needs are highest during early lactation. This pattern is typically associated with the physiological demands of milk production, as cows require greater nutrient intake to support lactation (Ingvarsen, 2006). Similarly, higher DTB for rumination during early lactation is expected, according to hypotheses saying that cows in earlier lactation stages spend more time ruminating to optimize fibre digestion and nutrient absorption, which is crucial for higher milk production (Soriani et al., 2012). However, as cows progress through lactation, they may prioritize other activities, such as resting or social interactions, potentially impacting rumination time (Phillips et al., 2013). The relationship between lactation stage and behavioural time budgets highlights the need for targeted management strategies that should consider these behavioural dynamics. Ensuring adequate access to high-quality forage and minimizing stressors during critical lactation periods may enhance both welfare and productivity in dairy herds (Wang et al., 2016).

Lactation stage time budgets for Grazing, rumination, and idling were primarily influenced by the lactation stage. These findings align with recent research, which indicated that physiological demand and pasture conditions are the principal factors regulating time-budget allocation in grazing systems (O'Driscoll et al., 2019; John et al., 2016). Cows in the early lactation phase spent the most time grazing,

while rumination and idling were at their highest during mid-lactation, and grazing time sharply decreased in late lactation; DSTB values are consistent with LSTB. The behavioural changes across lactation reflect the metabolic demands of dairy cows. During early lactation, cows are at risk of negative energy balance due to high milk production. Therefore, the increase in grazing time may represent a compensatory response to maximize dry matter intake (Roche et al., 2013; Gregorini et al., 2015). The lower rumination time during this stage may be related to longer grazing periods and higher pasture digestibility, as more digestible diets require less rumination per unit of intake (Beauchemin et al., 2008). In mid-lactation, increased rumination and idling suggest a shift towards greater digestive activity and behavioural stability as cows approach energy balance. By late lactation, reduced grazing activity likely reflects declining milk production and lower nutrient requirements, consistent with previous studies using automated monitoring systems (Rehman et al., 2020). Overall, these findings demonstrate that dairy cows dynamically adjust their behavioural time budgets in response to changing physiological demands over the lactation season. In addition, breed and its interaction with LS only influenced idling behaviour in LSTB. These differences may reflect variation in production demands, intake capacity, and adaptability among genetic groups (Prendiville et al., 2010; Vance et al., 2015). Moreover, the year significantly influenced all behavioural LSTB, reflecting the effects of environmental variation such as pasture availability, growth, and climatic conditions. Changes in grazing behaviour may result from differences in pasture height and bite intake, with cows increasing grazing time under restricted forage conditions (Pulido et al., 2018). The significant interaction between Year and LS for all behavioural LSTBs suggests that environmental effects vary with physiological demands, with early-lactation cows being more sensitive to pasture limitations and climatic stress (Mattachini et al., 2019).

Year-to-year variation was the strongest driver of grazing, rumination, and idling whole lactation period time budgets. This highlights the dominant role of environmental and management factors, including climate, pasture availability, forage quality, and supplementation, in shaping cow behaviour in grazing systems (Bargo et al., 2003; Gregorini et al., 2009). Cows adjust their activity patterns to optimize nutrient intake under changing pasture conditions, with recent studies confirming that environmental variability explains a substantial proportion of behavioural variation in pasture-based systems (Iqbal et al., 2022, 2023). The higher behavioural activity observed in Year 2 may reflect improved pasture conditions or differences in feed management.

The behavioural dynamics identified in this study offer several practical applications for pasture-based dairy farms. These findings highlight the importance of targeted early lactation management through improved pasture allocation and supplementation to support intake and reduce energy deficits (Roche et al., 2013). For example, breed had no effect on grazing or rumination but influenced idling behaviour, indicating that core feeding behaviours are relatively stable across genotypes under similar management conditions. Differences in idling may reflect variation in feed efficiency, intake capacity, and adaptability among breeds (Prendiville et al., 2010; Kolver et al., 2002; Buckley et al., 2000). Lactation age had no significant effect on behavioural time budgets, suggesting that grazing and rumination patterns remain relatively consistent across parities. Previous studies indicate that parity has limited influence on grazing and rumination durations, which are more strongly affected by diet and management conditions (Phillips,

2010; Beauchemin, 2018). The limited effects of breed and lactation age likely reflect the high behavioural flexibility of dairy cows. Grazing and rumination are adaptive processes primarily influenced by feed availability, quality, fibre intake, and environmental conditions rather than intrinsic traits (Gregorini et al., 2009, 2012; Beauchemin, 2018). This behavioural plasticity allows cows to adjust activity patterns to maintain energy balance and rumen function under changing conditions.

Understanding these behavioural patterns and time budgets is vital for optimizing management practices in dairy herds. Strategies that enhance grazing efficiency and promote rumination can improve animal welfare and productivity. For instance, ensuring access to high-quality forage and minimizing competition during feeding can support rumination and overall well-being (Wang et al., 2016). Additionally, monitoring behavioural changes throughout lactation can help identify cows that may require targeted nutritional interventions to maintain health and production levels. In summary, these findings underscore the importance of considering the lactation stage when assessing the behavioural time budgets of dairy cows. Future research should focus on elucidating the underlying factors influencing these behaviours and developing management practices that support optimal grazing and rumination throughout lactation. Moreover, automated behaviour monitoring can aid early detection of health and environmental stress, while adaptive grazing strategies and breed selection can improve resilience under variable pasture conditions (Mattachini et al., 2019; Pulido et al., 2018). Maintaining adequate grazing and rumination time remains essential for optimizing productivity and animal welfare.

5. Conclusion

Grazing dairy cows spend most of the daytime grazing to maximise energy intake, and most of the nighttime ruminating on the grazed herbage. Grazing activity appears to be high at dawn and at dusk, with the latter being more intensive. Grazing and ruminating patterns are not different between different breed groups, although Jersey cows spend slightly more time grazing and HFR cows spend slightly more time ruminating. Cows in the first lactation graze continuously with fewer resting intervals compared with those in higher lactations. Time of the day and seasonal variations suggest that grazing cows can adjust their behaviour patterns according to day length. Cows spend less time grazing and ultimately less time ruminating when pasture has been supplemented with additional feeds. Time budgets for the behaviour activities over 24 hours do not vary between breeds or lactation groups. Whereas variations in time budgets are observed during different seasons and for different feeds. The lactation stage was the primary factor influencing the lactation stage time budget, with year-related environmental variation also affecting activity patterns. Behavioural monitoring can support improved pasture management, productivity, and welfare. Environmental and management factors were the primary drivers of cow behaviour over the lactation period, highlighting the importance of optimized pasture and feeding strategies for improving performance and welfare.

Declarations

Animal Ethics Approval

All protocols regarding care and handling of the study animals in this research were approved (Protocol No. 18/58) by the Animal Ethics Committee, Massey University, New Zealand.

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Authors' contributions

Muhammad Wasim Iqbal executed and managed the research study and prepared this manuscript. Ina Draganova, Patrick Morel, and Steve performed the supervision of analysis, and drafting of this manuscript.

Competing interests

The authors declare not conflict of interest.

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Figures

Figure 1. Animal Model and Selection for the Study

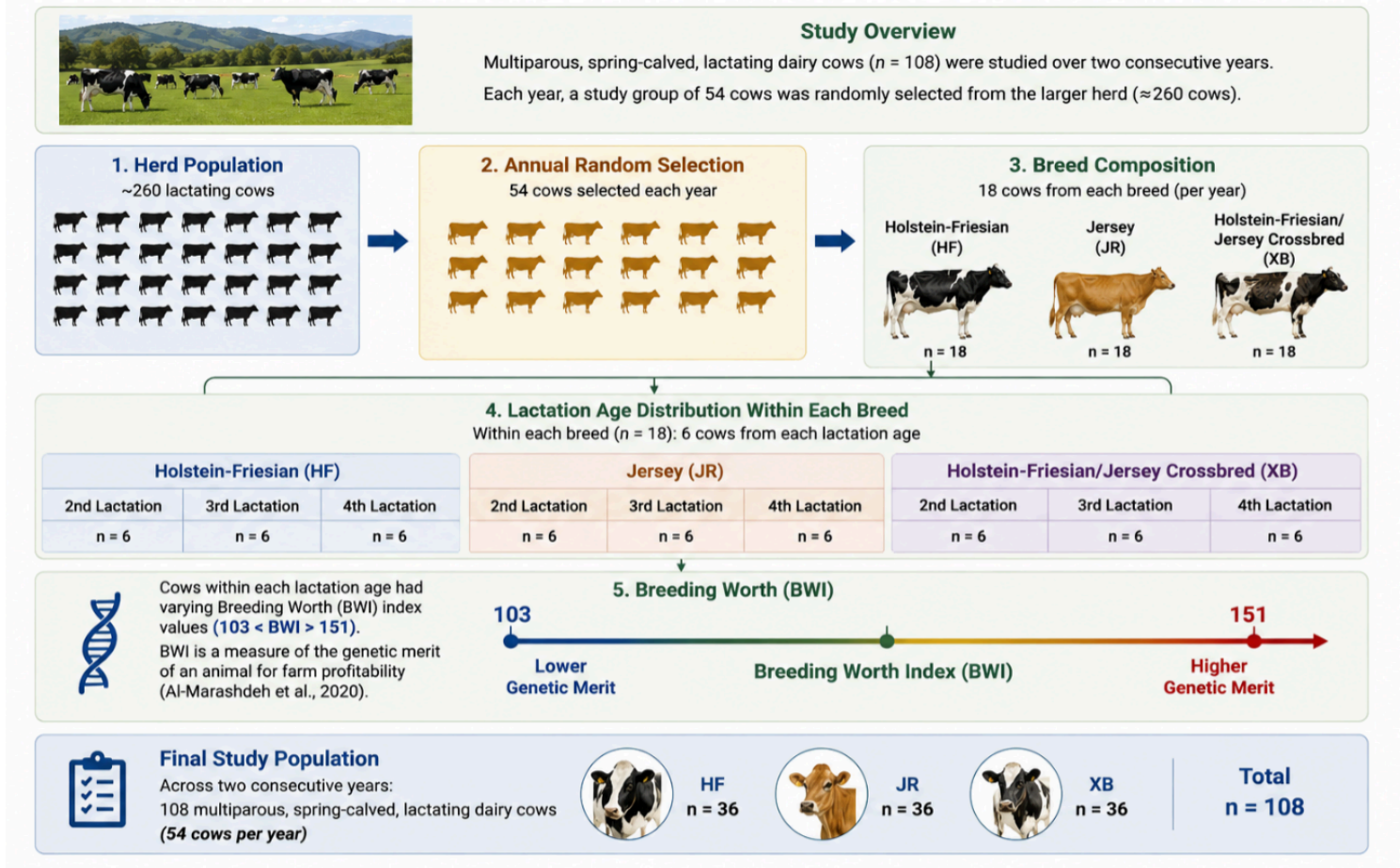


Figure 1

Schematic representation for the selection of experimental animals over two years of the study period.

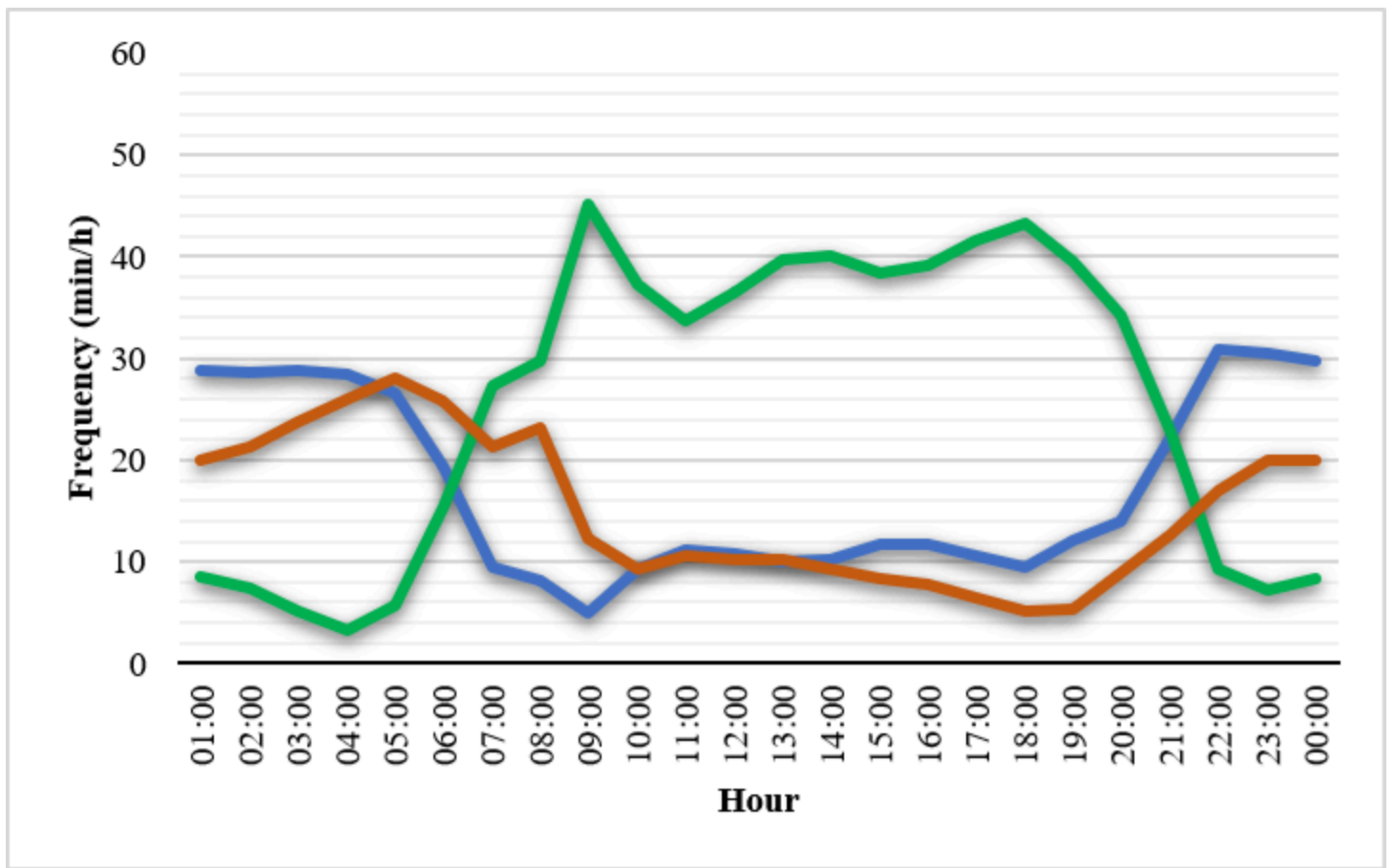


Figure 2

Frequency of grazing and rumination and idling behaviours of grazing dairy cows ($n = 108$) at each hour over 24 hours. (Green, blue and red lines show grazing, rumination and idling behaviours respectively. Standard errors of means for each behaviour for the individual hours are shown in Table S1).

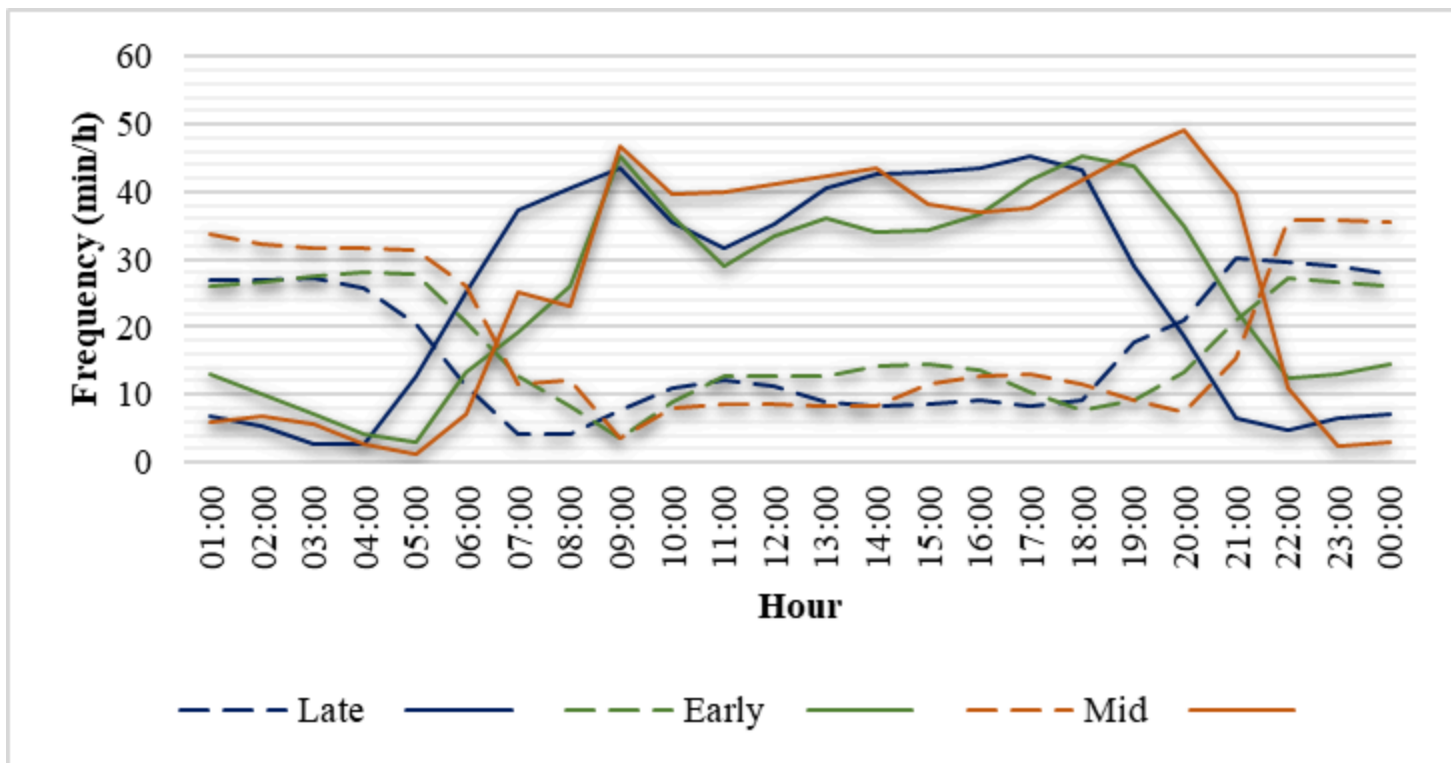


Figure 3

The 24-hour frequency of grazing and rumination behaviours of grazing dairy cows (n = 108) during different stages of lactation. (Compact lines show grazing and dotted lines show rumination. Standard errors of means for each behaviour for the individual hours are shown in Table S2)

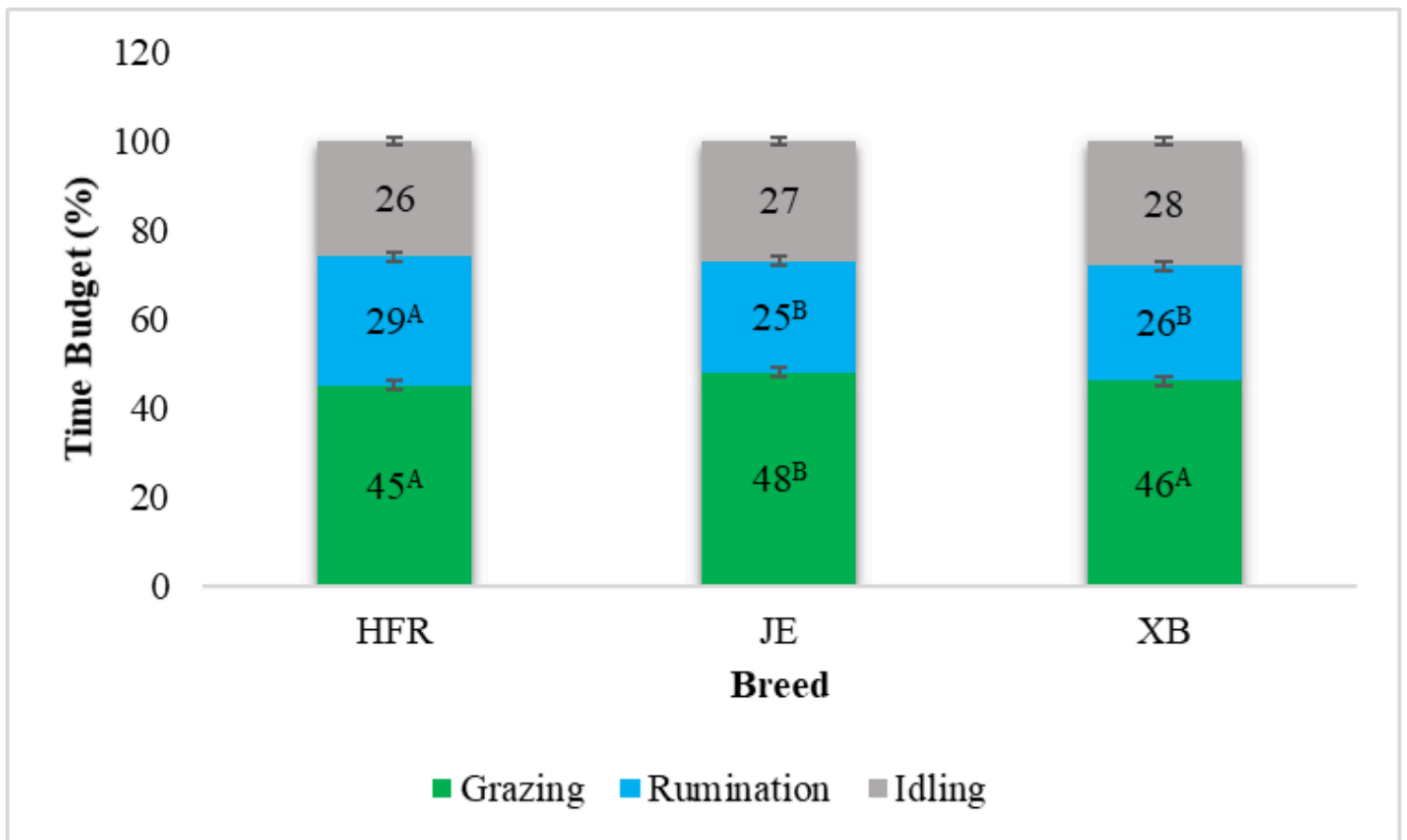


Figure 4

The daily time budgets for grazing, ruminating, and idling behaviours in grazing dairy cows (n = 108). The number of hours spent on each behaviour over 24 hours are presented in their percentage. (HF = Holstein-Friesian, JR = Jersey, XB = Crossbreed).

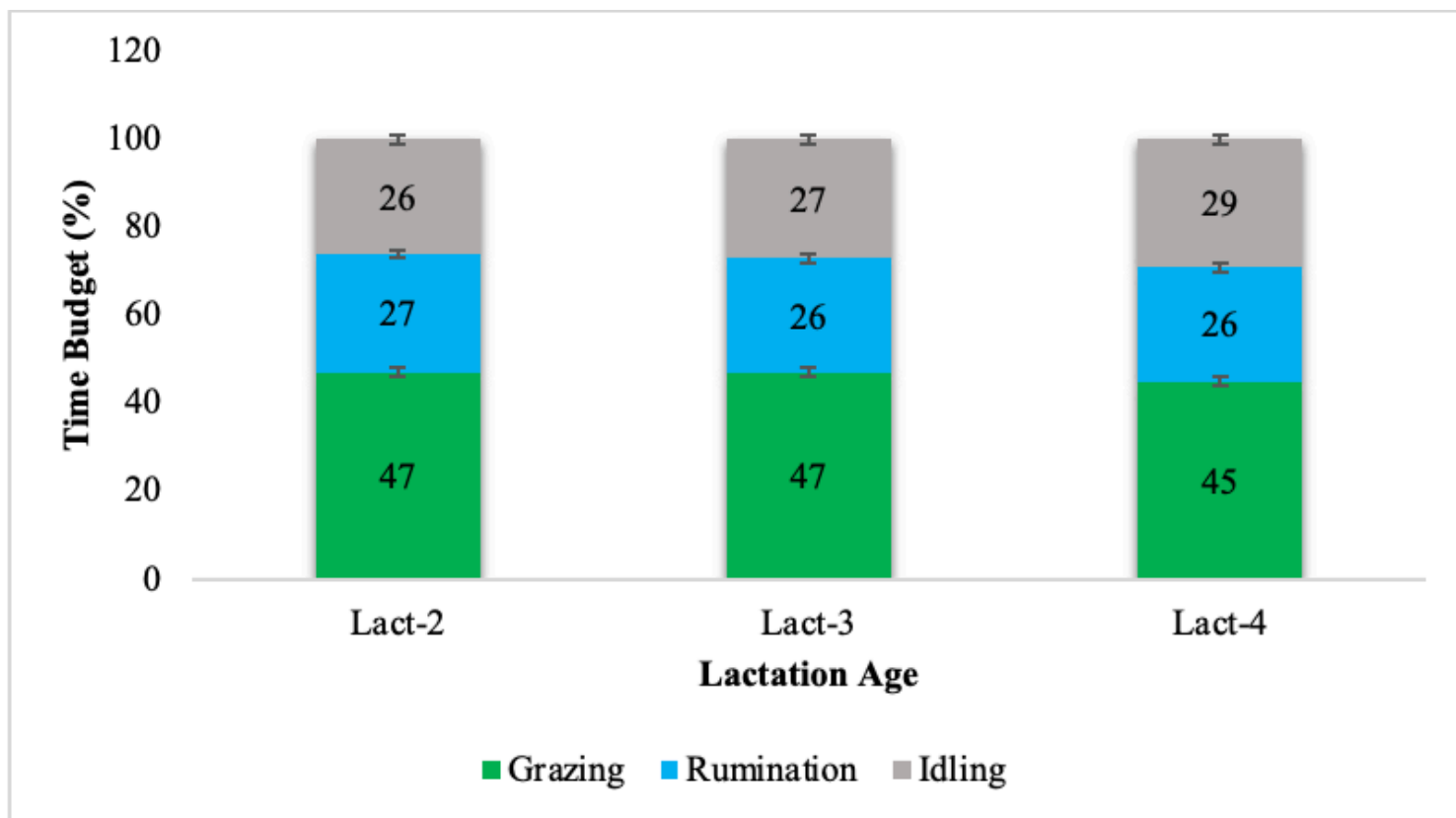


Figure 5

The daily time budgets of grazing dairy cows (n = 108) for grazing, ruminating, and idling behaviours over 24 hours. The number of hours spent on each behaviour over 24 hours are presented in their percentage. (Lactation age represents cows with second, third, and fourth lactations, respectively).

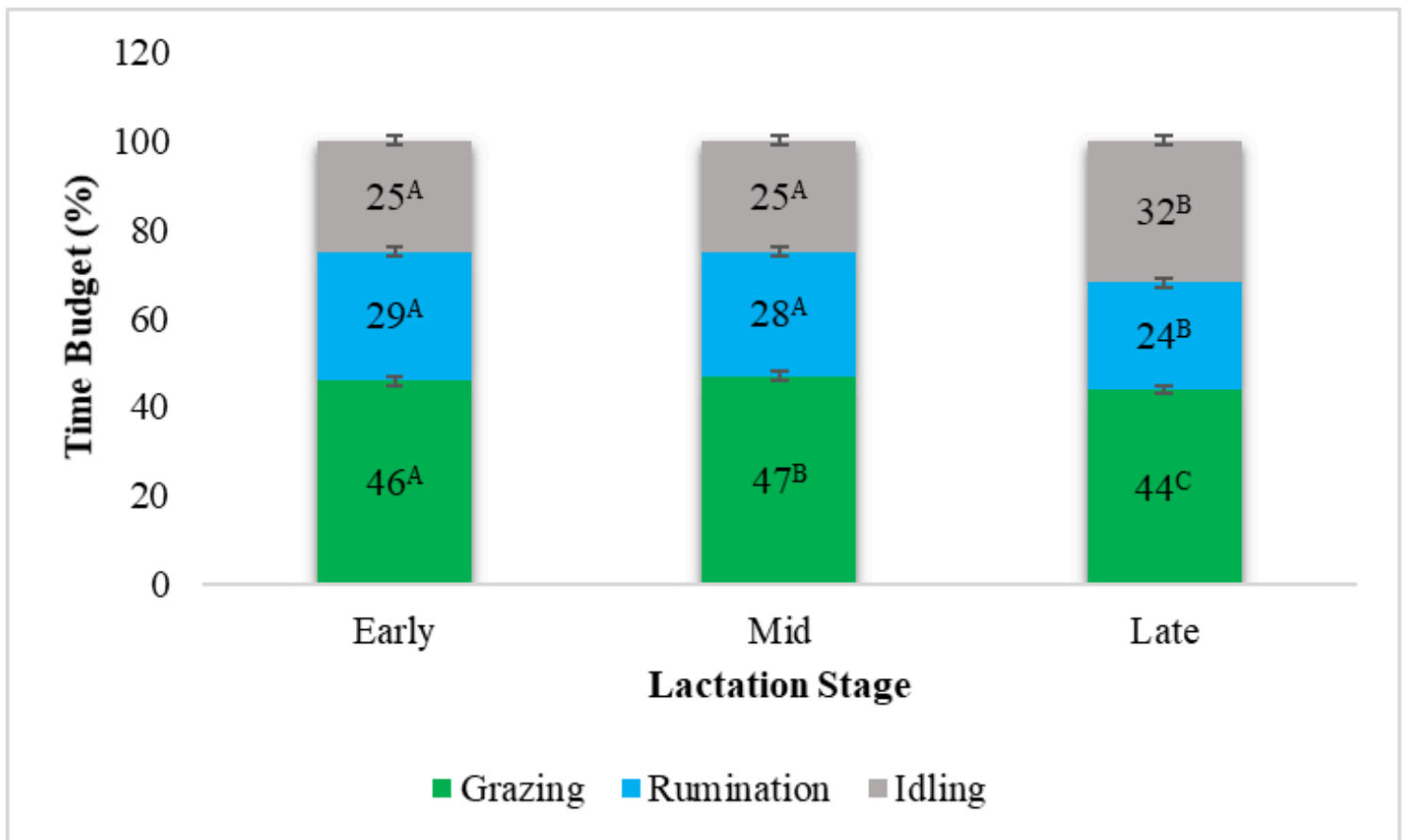


Figure 6

The daily time budgets of grazing dairy cows (n = 108) for grazing, ruminating, and idling behaviours over 24 hours for different stages of the lactation period. The number of hours spent on each behaviour over 24 hours are presented in their percentage.

Supplementary Files

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