The effect of feeding fodder beet or kale during winter on growth and behaviour of rising-one-year-old dairy heifers

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Abstract

While fodder beet (FB) has been used by the dairy industry for winter grazing over the last 10 years, there is no published information on its effect on heifer performance. Farmers have recently expressed concern regarding the suitability of fodder beet for wintering growing dairy heifers due to the low crude protein (CP) content of the FB bulb. To compare liveweight gain and grazing behaviour, 191, 9- to 12-month-old heifers at the Southern Dairy Hub were offered either FB (n=93; HFR-FB) or kale (n=98; HFR-Kale), both with pasture baleage as a feed supplement, in winter 2019. Allocations were formulated to achieve similar energy intake, but HFR-Kale were offered a higher proportion of their diet as baleage. There were no differences in apparent DM intake, but HFR-FB consumed a diet with overall lower CP (11.4%) than did HFR-Kale (13.4%). Heifers in both treatments had a similar average daily liveweight gain (0.45 ± 0.083 kg/day) but neither group achieved the 0.6 kg/day average daily gain target for heifer growth. Differences were observed in eating and ruminating behaviour between the two groups, but more research is required to validate the measurement devices used in this study for animals grazing crop. The results indicate the challenges of achieving industry-recommended growth rates over winter in heifers grazing forage crops and highlight the importance of feed testing for nutritive value to ensure nutrient requirements are being met.

Keywords: Live weight; *Beta vulgaris*; *Brassica oleracea*; allocation; intake; feed quality

Introduction

For dairy heifers, meeting their mature liveweight targets to achieve good lifetime productivity and reproductive success requires achieving consistent monthly growth rates. Industry targets suggest reaching 30% of mature weight at 6 months, 60% at 15 months (mating), and 90% at 22 months (pre-calving) (Troccon 1993). To meet these targets, both metabolisable energy (ME) and protein requirements need to be met. The importance of the winter period in achieving growth-rate targets is that in the 19 months between weaning and first lactation, over 30% of the heifer's growth (from 8-11 months and 20-23 months of age) occurs during the cool months of winter. For southern regions of the South Island, winter represents the industry's most-challenging feeding period with low pasture growth (Dalley & Geddes 2012), and corresponds with the lowest level of achievement of liveweight-gain targets (Handcock et al. 2017).

Historically, forage crops such as kale (*Brassica oleracea*) and swedes (*Brassica napus*) have been used for wintering dairy cattle in the South Island of New Zealand (White et al. 1999; Nichol et al. 2003). In recent years, there has been increased interest in feeding fodder beet (FB; *Beta vulgaris*) as an alternative to winter brassicas. This has been driven from a perceived lower cost/kg dry matter (DM) to grow FB compared with kale, its ability to produce high yields, a smaller area requirement (Gibbs et al. 2011), and environmental benefits from a lower nitrogen content in the bulb (Waghorn et al. 2018). Furthermore, as FB yields increase, the quality does not decline, unlike kale, where the stem begins to lignify towards the end of winter (Matthew et al. 2011).

In regions where winter forage crops are the predominant feed source for rising-one-year-old dairy heifers, the extent to which forage type affects animal growth rate is unclear. Many feeding decisions are driven predominately by cost, practicality (ease of feeding and management, fit with the system), and environmental considerations to reduce nutrient losses, rather than the ability of the diet to meet the nutrient requirements, especially protein and energy, with most winter diets being allocated on a DM basis.

The objective of this observational study was to compare the growth of rising-one-year-old dairy heifers grazing either kale or FB from May until August and determine if crop type affected grazing behaviour and rumination. It was hypothesised that the lower crude protein (CP) content of the FB bulb would result in insufficient dietary nitrogen to meet the nutritional requirements for growth.

Materials and methods

The experiment was conducted at the Southern Dairy Hub (SDH), Wallacetown, Southland, New Zealand (46.3298° S, 168.2903° E) between the 30th of April 2019 and the 20th of August 2019, with approval from the AgResearch Animal Ethics Committee (AE Application: 14814).

This study was an un-replicated longitudinal observational study involving 191 Friesian-Jersey crossbred heifers (9-12 months of age). These animals were allocated to winter diets that matched the diet of their dam when *in utero* (93 to FB: HFR-FB, 98 to kale: HFR-Kale) as they were the heifer replacements in a multi-year farm-systems study.

Transition from pasture to FB occurred between the 1st and 13th May. The initial allocation was 0.5 kg DM/head/day for three days with pasture and pasture baleage making up the remainder of the diet. The allocation was then increased by 0.5 kg DM/head every two days until the full target allocation of 5.4 kg DM/head/day was achieved. Pasture allocation was reduced as FB intake increased. The transition from pasture to kale started later on the 22nd May due to limitations in the availability of kale resulting from lower than expected yields. Their allocation started at 2 kg DM/heifer/day and increased by 0.5 kg DM/head per day until the target allocation of 4.1 kg DM/head/day was achieved after five days. Pasture baleage was offered to both groups *ad libitum*, in round-bale feeders, while transitioning onto crop. Diet DM allocations were determined using DairyNZ's winter-crop allocation calculator (DairyNZ 2015) based on the predicted quality of each feed and expected utilisation. The HFR-Kale animals remained on the crop until the 6th August, when all the kale had been consumed, and then grazed pasture while HFR-FB heifers had sufficient crop to graze FB until 19th August. During the experiment HFR-FB, were offered 2.6 kg DM/day baleage and HFR-Kale, 3.7 kg DM/day baleage. The combined allocation of crop and baleage was designed to supply 72 MJ ME/heifer/day. A fresh break of crop and the daily baleage allocation were offered once-daily at approximately 0700 h. Intakes for crop and supplement were pooled for each month and average intake (or allocation) was determined. Reticulated water was provided using portable water troughs located close to the feed face. A back fence was used in both crop paddocks to restrict movement and was moved closer to the feed face twice per week.

Twenty animals were randomly selected from each group to be fitted with a CowManager electronic tag (CowManager SensOor, Agis Automatisering BV, Harmelen, the Netherlands; validated in cattle grazing pasture by Pereira et al. 2018). The tags monitored daily grazing, ruminating, activity and resting (idle) using a proprietary model with the data expressed as percentage of behaviour per hour and per day. These devices automatically downloaded data to a server through readers installed near the paddocks between the 3rd and 12th July. Two tags from HFR-FB failed to collect data, leaving 18 and 20 animals contributing data for HFR-FB and HFR-Kale respectively.

Crop DM yield was determined for kale on the 20th May, 19th June and 12th July and for FB on the 21st May, 18th June and 12th July. For kale, two 1m^2 quadrats were randomly selected from the area to be grazed over the next two weeks. All plants from within the quadrat were cut to ground level and weighed. For FB, yield was assessed from two 2-m double rows of crop in the next area of the paddock to be grazed. All FB plants were pulled from the ground, soil removed, and the fresh weight of leaf and bulb recorded separately (Dalley et al. 2020). Two representative stem/bulb/FB leaf subsamples were retained from each plot at each harvest and used to determine the DM content. Dry weight was determined after drying at 100°C to constant weight. Samples of crop and supplement were sent to Hill Laboratories (Hamilton, NZ) for DM, nutritive quality and mineral analysis by a near infra-red spectrophotometer (NIRS, NIRSystems, Foss, Maryland, USA). Post-grazing crop residual harvests for FB and kale were completed on the 21st June and 22nd July using the same process described for the pre-crop assessment except that samples were not sent for quality analysis. Crop yield and residual measurements were used to estimate apparent intake of DM, energy and CP using feed-quality results from Hill Laboratories.

Unfasted heifer live weight prior to the daily allocation of crop was measured on the 11th April, 30th April (pre-winter), 6th June (early-winter), 12th July (mid-winter), 20th August (post-winter) and 15th October (pre-mating) using Tru-Test weigh scales (Datamars SA, Lamone, Switzerland). Stature measurements of wither height, body length and girth circumference were taken pre-winter, post-winter and pre-mating using a standard tape measure and measuring band.

Statistical analysis

All analyses were performed using Genstat (Version 19.1.0.21390, VSN International Ltd., Hemel Hempstead, UK). Means for crop and animal measurements were compared using a general linear model. Descriptive statistics (means and standard deviations) for diet composition and apparent intake of crop and supplement are presented. Liveweight gain was compared using repeated-measures analysis using crop as the fixed term, animal as the random term across the six measurement dates. Animal behaviour measures for individual heifer means were combined within measurement dates and date used as the random term.

Results

Crop yield and feed quality

The average crop yield for kale (12.6±1.84 t DM/ha; mean±SD) was significantly ($P<0.001$) less than that for FB (22.4±3.83 t DM/ha). The FB crop averaged 19±5.2% leaf.

Fodder beet bulb had higher DM than FB leaf ($P<0.05$), with kale intermediate (Table 1). The baleage DM content was higher than that of both crops ($P<0.05$). The fibre content was greatest in the baleage, which also had the lowest organic matter digestibility (OMD). The dietary components differed in ME ($P<0.001$) with the FB bulb having the highest and the baleage the lowest MJME/kg DM. There was a trend for the CP content of the FB bulb to be less than that of all other feeds ($P<0.10$). There were no statistically significant differences in mineral composition between feeds, though kale tended to contain more calcium ($P<0.10$).

Feed allocation and nutrient intake

Estimated daily DM allocation was similar between the treatment groups, however, HFR-FB received a diet

Table 1 Average composition of fodder beet (FB) bulb and leaf, kale, and pasture baleage eaten by heifer replacements during winter 2019. Means with the same letter (a-c) within a row are not significantly different at the 5% level. SEM = standard error of the mean.

	Baleage	FB bulb	FB leaf	Kale	SEM	P value
Dry matter %	52.2[a]	16.6[b]	8.9[c]	12.0[c]	1.85	<0.001
Organic matter digestibility (%)	67.8[c]	95.7[a]	86.8[b]	85.9[b]	3.28	0.002
Crude protein (%)	14.0[b]	9.1[b]	20.1[a]	13.5[b]	2.48	0.099
Neutral detergent fibre (%)	50.0[a]	10.3[c]	24.1[b]	25.2[b]	1.91	<0.001
Metabolisable energy (MJ ME/kg DM)	9.8[c]	14.7[a]	11.2[b]	12.4[b]	0.60	<0.001
Calcium (%)	0.70[b]	0.12[c]	0.40[bc]	1.33[a]	0.266	0.077
Magnesium (%)	0.22	0.16	0.34	0.21	0.875	0.536
Phosphorus (%)	0.31	0.18	0.19	0.29	0.049	0.182

Table 2 Summary (mean and standard deviation, SD) of average allocation and estimated intake of fodder beet (FB), kale or baleage dry matter, energy and nitrogen offered to 2018-born replacement dairy heifers during winter 2019 and average eating, ruminating and activity (minutes/day).

Diet allocation and intake	HFR-Kale	SD	HFR-FB	SD
Total feed allocation (kg DM/heifer/day)	8.3	0.78	7.8	0.72
Baleage allocation (kg DM/heifer/day)	3.7	0.49	2.5	0.52
Crop allocation (kg DM/heifer/day)	4.5	0.40	5.3	0.39
Baleage intake (kg DM/heifer/day)	3.0	0.39	2.0	0.39
Crop intake (kg DM/heifer/day)	3.4	0.30	4.5	0.33
ME intake (MJ/heifer/day)	71.4	8.40	76.5	6.73
Nitrogen intake (g/heifer/day)	135	7.0	118	10.5
Diet crude protein content (% DM)	13.3	0.67	11.4	0.11
Grazing behaviour	**HFR-Kale**	**HRF-FB**	**SED**	**P-value**
Eating (mins/day)	398	304	19.2	<0.001
Ruminating (mins/day)	315	397	14.5	<0.001
Idle (mins/day)	336	308	15.9	0.120
Active (mins/day)	332	376	13.1	0.030

comprising 68% crop compared with only 54% for HFR-Kale. The HFR-FB animals ate 1.1 kg DM/heifer/day more crop than did HFR-Kale over the winter period (Table 2). Estimated ME intake did not differ between the treatment groups however, HFR-FB had a diet with 14% less CP (Table 2) and, thus, HFR-FB heifers had a lower N intake (13% lower than HFR-Kale).

Live weight and stature

An interaction between crop and time for live weight showed that HFR-Kale were heavier than HFR-FB at the start of the study, both groups had similar weights at the mid-point and HFR-Kale were heavier at the final weighing in October (Fig. 1). Daily liveweight gain between pre- and post-winter measurements did not differ between treatments, averaging 0.46±0.083 kg for HFR-Kale and 0.45±0.093 kg/day for HFR-FB. There were no differences in girth (151.0±0.64 cm) or length (108.7±0.24 cm) between treatments, but HFR-Kale were taller (112.5±0.37 cm), ($P<0.001$) than were HFR-FB (110.9 cm).

Animal behaviour

HFR-Kale spent, on average, 134 extra minutes/day eating ($P<0.001$) and 83 fewer minutes/day ruminating ($P<0.05$) compared with HFR-FB (Table 2). The idle time did not differ between treatment groups, but HFR-FB were more active ($P=0.030$).

The grazing intensity (i.e., minutes eating per hour) increased for both treatment groups from 07:00 hours, corresponding with the offering of a new break of crop and the daily baleage allocation (Fig. 2a). Grazing intensity gradually decreased throughout the day as crop availability declined. Between 07:00 and 16:00, HFR-Kale spent 10-15 more minutes per hour eating. A decrease in eating time for both treatments occurred at 17:00 hours, corresponding with the onset of darkness.

Average rumination time during daylight hours was 7.9 and 4.4 min/h for HFR-FB and HFR-Kale respectively (Fig. 2b). Rumination time for both treatments was less than 10 min/h between 07:00 and 12:00 hours (Fig.2b). Rumination time increased for both treatments after 17:00 hours to a peak of 24-29 min/h at 04:00 and 05:00 h. HFR-FB were more active between 07:00 to 11:00 hours following the allocation of fresh feed (Fig. 2c).

Discussion

The aim of the study was to monitor the performance of rising-one-year-old dairy heifers when managed in crop-wintering systems typical of those offered in the southern South Island and identify any nutritional or performance risks. While average daily liveweight gain between 30th April and 20th August 2019 for both groups was similar (ADG; 0.45-0.46 kg/day), neither group achieved the 0.6 kg/day ADG target for heifer growth between 6 and 15 months of age (Roche et al. 2015). It was estimated that sufficient DM (7.8 and 8.3 kg DM/heifer/day for HFR-FB and HFR-Kale, respectively; Zhang et al. 2016) and energy

Figure 1 Average live weight of 2018-born dairy heifers before, during and after winter when grazed on either kale (———) or fodder beet (FB ———) during winter 2019.

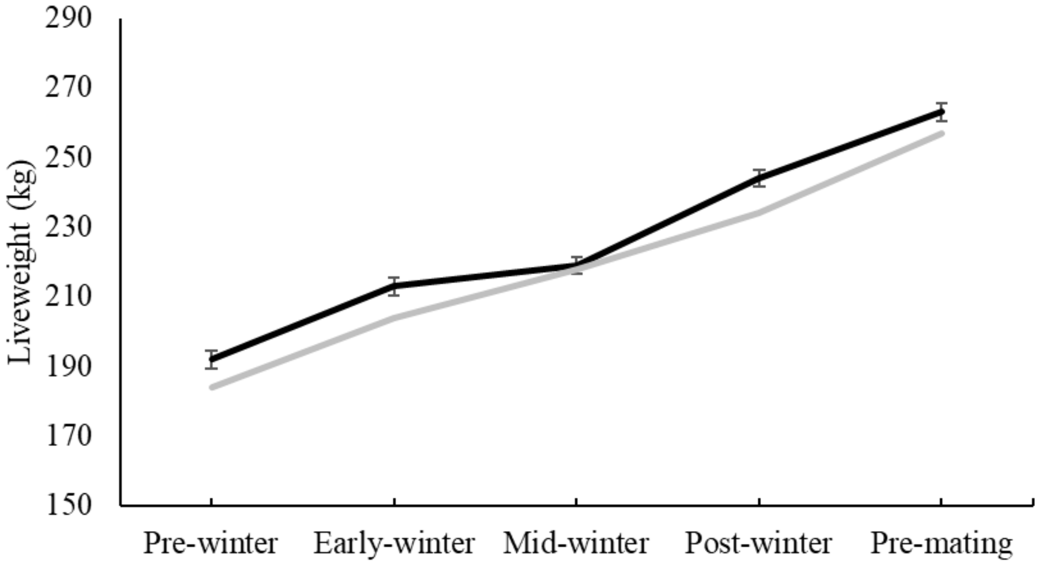
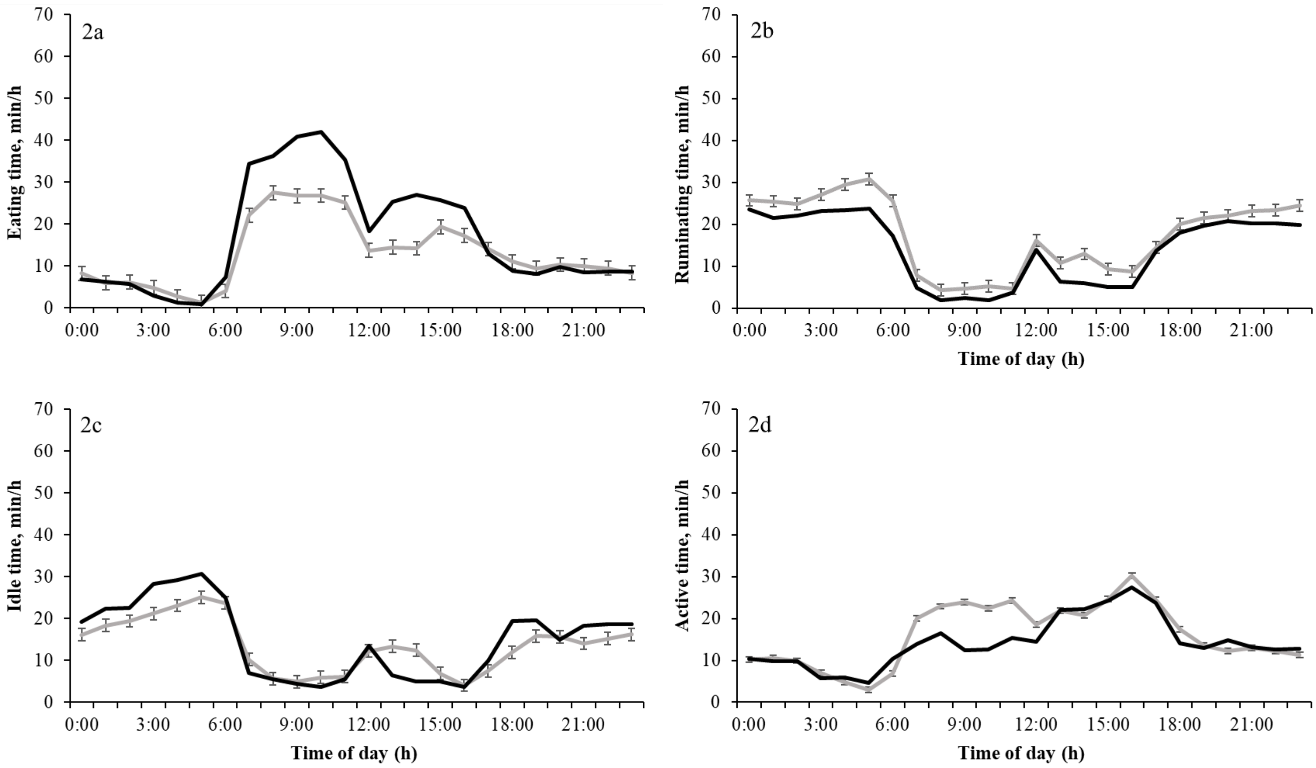


Figure 2 Mean a) eating time (min/hour), b) ruminating time (min/hour), c) idle time (min/hour) and d) active time (min/hour) for each treatment compared over a day for dairy heifers wintered on fodder beet (FB ———) or kale (———) for a nine-day period from the 3rd to the 12th July. Error bars are 1 standard error of the difference (SED).



(76 and 71 MJ/head/day) was offered to achieve this gain. Heifers grazing kale were offered more total DM to account for an expected lower kale utilisation (Edwards et al. 2014; Dalley unpublished data).

Heifers in HFR-FB and HFR-Kale consumed 3.0% and 2.9% of their live weight daily, respectively. In contrast, Saldias and Gibbs (2016) reported that beef steers offered *ad libitum* FB consumed 2% of LW but gained 1.0 kg/head/d. The discrepancies in intake and liveweight gain between the current study and that of Saldias and Gibbs (2016) could relate to the age, breed and gender differences of the experimental animals, along with inherent difficulties in determining yield and utilisation of FB crops (Gibbs et al. 2011) which are required to estimate intake.

For both treatments, the CP content of the diet was lower than the minimum requirement for optimising growth of 15-17% DM (Alderman & Cottrill, 1993) with the FB diet only averaging 11.4% CP (Table 2). The low

CP content of the kale diet was surprising given kale is known for its ability to take up large amounts of excess N (Fletcher & Chakwizira, 2012) and the CP content of 71 kale samples from crops grown at SDH from 2017 to 2021 averaged 16.5% with 66% containing more than 15% CP (unpublished results). The kale crops in the current study were lower in DM yield than expected and this may have contributed to the lower CP content. Given neither group achieved the target daily LWG of 0.6 kg/day and both diets were low in CP, we hypothesize that protein intake restricted growth. This result highlights the importance of testing all winter feeds for nutritive value and formulating winter diets to ensure nutrient requirements are being met, rather than just allocating feed on a DM basis.

The heifers used in the current study were part of a larger farm-systems experiment investigating potential cumulative effects of feeding FB to mixed-aged cows in late lactation, the dry (winter) period and early lactation. At one day of age, HFR-FB were, on average, 9% lighter (unpublished data) than HFR-kale and, despite co-rearing of animals from two days of age, they remained lighter and smaller in stature at the start of winter (8-9 months of age; Fig. 1). Hammond et al. (2021) also reported lower body weights and growth rates and higher mortality rates of twin lambs born to ewes fed FB in mid-to-late gestation, indicating dietary impacts on offspring while *in utero.* The numerical differences in LW between the HFR-FB and HFR-Kale in the current experiment persisted until at least pre-mating. To statistically determine the impact of crop type on heifer intake and liveweight gain over winter, a replicated trial would be required where a single cohort of animals were allocated to the treatments prior to winter, ensuring the treatment groups were balanced for age, breed and live weight.

Troccon (1993) recommended that heifers should be 30%, 60% and 90% of mature live weight at 6, 15, and 24 months of age, respectively, requiring a linear trajectory of growth. However, both the availability of feed and the quality of available feed will vary, particularly when heifers are reared in grazing systems. In our study, both groups failed to achieve the 60% of mature liveweight target at 15 months of age, with the HRF-Kale achieving 54% and HFR-FB 52%. McNaughton and Lopdell (2012) reported that 9- to 12-month-old heifers with very low growth rates during their first autumn/winter, were not able to regain the target trajectory. However, an industry review of heifer growth targets by Roche et al. (2015) reported that a ‘phased nutrition regime’ where periods of feed restriction are followed by periods of re-alimentation may be better suited to heifer rearing in grazed dairy systems. Further research to determine the best option could take two approaches. One would be to determine whether rising-one-year-old heifers who do not reach their 15-month liveweight target following wintering on crop can achieve compensatory growth through improved nutrition to meet their 24-month targets. The second approach would be to investigate options to improve the birth weight and growth performance of calves in their first year, to avoid the need for compensatory growth, given the known challenges of providing sufficient nutrition to this class of stock during winter and/or summer, depending on regional pasture growth supply and quality.

The differences in the crop:baleage ratio for the two groups was intentional and resulted from lower-than-expected kale yields. To balance the winter-feed budget and ensure the required daily DM and energy allocations for HFR-Kale for the winter period were achieved, additional baleage was offered. Even with the revised allocation, HFR-Kale finished their crop on the 6th of August and returned to pasture grazing while HFR-FB stayed on crop until the 19th of August.

In the current observational study, there were differences in grazing, ruminating and activity behaviour between the two groups. Generally, time spent eating/h for both treatments increased rapidly from 07:00 hours, immediately after the daily allocation of fresh feed. Data indicate that HFR-FB ruminated more from 12:00 to 15:00 compared with the HFR-Kale and HFR-FB were more active in the period immediately after the allocation of fresh feed (Fig. 2 a-d). Across the day, HFR-Kale ate for 6 h 36 min and HFR-FB ate for 5 h 4 min, considerably lower than the >7 h/day grazing observed by Saldias and Gibbs (2016). There might be several reasons for differences between the groups in their eating behaviour, but a key driver for variation between visually observed behaviour and the SensOor eartags relates to calibration of the sensors. Periera et al. (2018) validated the tags under pasture grazing, however, animals on crops, especially bulb crops, move their mouths and heads differently when compared with animals grazing pasture, potentially affecting how the algorithms assign motion to grazing and ruminating. Further research is required to validate the SensOor tags in animals grazing crops to verify the behavioural differences observed in this study.

Conclusion

In this observational study, rising one-year-old dairy heifers were unable to achieve the recommended 0.6 kg/day liveweight gain targets between May and August when wintered on diets based on either kale or FB. As a result, they were only 52-54% of mature live weight at 15 months of age rather than the recommended 60%. For both diets the recommended dietary CP content of 15-17% for optimum growth was not achieved, potentially contributing to the lower liveweight gain. The results highlight the importance of testing feeds for nutritive value and adjusting winter diets to ensure nutrient requirements are being met. While differences in grazing and ruminating behaviour between HFR-FB and HFR-Kale were observed more research is required to validate the SensOor tags in animals grazing crop.

Acknowledgements

This project was funded by the dairy farmers of New

Zealand through DairyNZ Inc. (Hamilton, New Zealand), contract RDN1805. We thank C Crack and N Hammond for managing data collection and the farm team at the Southern Dairy Hub for animal management.

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