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RESEARCH ARTICLE

# Activity level of grazing dairy cows, as a criterion for grazing management in pasture-based dairy production systems

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## ABSTRACT

Various studies have evaluated the use of electronic devices to automatically record the grazing behavior of dairy cows. Linking individual grazing behavior of dairy cows with the modifications in grazing behavior across the grazing session through the use of automatically registered indicators, would allow the development of decision-making tools in grazing management. The objective of the present study was to evaluate the use of the activity level (AL) recorded with an accelerometer during the grazing-down process of a pasture grazed by dairy cows as a possible criterion for decision-making related to grazing management. A completely randomized design was used to evaluate the AL of dairy cows in two contrasting pasture-based dairy production systems: A pasture-based system with high concentrate supplementation level and high herbage mass (HM), using high-yielding dairy cows (GRAZSUP), and a pasture-based system with minimal concentrate supplementation level and medium HM, using Holstein New Zealand strain (GRAZ). Pre-grazing HM was higher in GRAZSUP than in GRAZ (+750 kg DM $ha^{-1}$), while forage removed was higher in GRAZ than in GRAZSUP (+1.9 kg DM $cow^{-1}$ $d^{-1}$). Although the production system influenced the characteristics of the pasture and the ingestive behavior of the dairy cows, when AL was evaluated as the proportion of the initial AL recorded at a time-point of the grazing-down process, there were no differences in each of the times evaluated. In conclusion, AL of grazing dairy cows was significantly affected during the grazing-down process, reflecting the modifications in grazing behavior across grazing session.

**Key words:** Grazing behavior, grazing management, grazing time, herbage mass, Lifecorder PLUS.

## INTRODUCTION

Pasture-based dairy systems require grazing managements that ensure an adequate daily allocation of high-quality herbage, but this is a laborious and time-consuming activity due to the required regular pre- and post-grazing pasture measurements. In pasture-based dairy systems that use grazing strips for the daily herbage allocation, a high proportion of the total DM intake is consumed during the first hours of the first grazing session (Gregorini et al., 2009; Gregorini, 2012). Recent studies have reported that, in the first 240 min of the grazing session, dairy cows can consume more than 50% of the daily DM intake (DMI), with high intake rates and a high proportion of time dedicated to grazing (Piña et al., 2020).

Various studies have evaluated the use of electronic devices to automatically record the grazing behavior of dairy cows (Ueda et al., 2011; Delagarde and Lamberton, 2015; Werner et al., 2019b), and thus understand how grazing management influences the grazing-down process to increase the grazing efficiency and DMI from pasture. In recent studies, it has been reported that the use of the activity level recorded with collar-mounted accelerometers in dairy cows allows to estimate grazing time with a high level of precision under contrasting grazing managements (Iqbal et al., 2021; Piña et al., 2021).

Usually, grazing management is based on pasture characteristics rather than animal behavior (Fulkerson and Donaghy, 2001). Few studies have analyzed the use of automatically registered indicators based on the behavior of dairy cows for grazing management (Werner et al., 2019a). Linking individual grazing behavior of dairy cows with the modifications in grazing behavior across the grazing session through the use of automatically registered indicators, would allow the development of decision-making tools in grazing management, especially if these indicators can be used in conjunction with other technologies associated with grazing management of dairy cows, such as Internet of things (IoT) devices or virtual fences. The development of new technologies that allow the automation of some tasks associated with grazing management could be an alternative to reduce labor cost in dairy systems (Halachmi et al., 2019).

The objective of the present study was to evaluate the use of the activity level (AL) recorded with an accelerometer during the grazing-down process of a pasture grazed by dairy cows in two different pasture-based production systems, as a possible criterion for decision-making related to grazing management.

## MATERIALS AND METHODS

### Experimental location

The experiment was conducted at two sites with contrasting pasture-based dairy production systems. One of the sites was a dairy production system with high-production Holstein Friesian strain (HF), focused to obtain a high milk production per cow with grazed-grass and concentrate supplementation. This experiment was conducted at the Agricultural Research Station of Austral University of Chile, Valdivia (39°47' S, 73°13' W), Chile, during 30 d in spring of 2017 (from 6 October to 6 November). The dominant species in the pasture were perennial ryegrass (*Lolium perenne* L.; 86%) and white clover (*Trifolium repens* L.; 8%), and it was established 2 yr earlier and subjected to strip-grazing management.

In contrast, a spring-calving Holstein New Zealand cows (HNZ) dairy production system was evaluated. This production system was focused to obtain a high milk production per hectare with grazed-grass and minimal supplementation. This experiment was conducted at Oromo Experimental Station of the University of Chile, Purranque (41°08’ S, 73°09’ W), Chile, during 30 d in summer of 2018 (from 3 January to 3 February). The dominant species in the pasture were perennial ryegrass (80%), white clover (8%) and cocksfoot grass (*Dactylis glomerata* L.; 5%), and it was established 3 yr earlier and grazed in a strip-grazing management. Although the different seasons of the year in which the study was carried out, the pasture in both systems were in an equivalent phenological state, due to a more delayed phenology at GRAZ.

### Treatments, animals and experimental design

All procedures in this experiment were approved by the Animal Welfare Committee of the Universidad Austral de Chile (grant number 255/2016).

A completely randomized design was used to evaluate the activity level (AL) of dairy cows during the grazing-down process in two contrasting pasture-based dairy production systems: A pasture-based system with high concentrate supplementation level and high herbage mass (HM), using high-yielding HF strain (GRAZSUP), and a pasture-based system with minimal concentrate supplementation level and medium HM, using HNZ strain (GRAZ).

In GRAZSUP, 12 dairy cows (n = 12) were used and selected according to the number of lactations (2.88 ± 1.7), days in milk (50.3 ± 11.8 d), milk production (31.6 ± 8 kg $cow^{-1}$ $d^{-1}$) and body weight (501.2 ± 74 kg). For GRAZ, also 12 dairy cows (n = 12) were used and selected according to number of lactations (4.5 ± 2.5), days in milk (138.5 ± 45.8 d), milk production (27.4 ± 6.3 kg $cow^{-1}$ $d^{-1}$) and body weight (520 ± 32 kg). Thus, to carry out the experiment, 24 cows (n = 24) were used in total. In both groups, evaluations lasted 30 d, including a 7 d adaptation period to allow the animals to adjust to the collar, and an experimental period of 23 d. A 5 ha paddock in each site was used, grazed in a strip-grazing system. Thus, the grazing strip was considered as the experimental unit to analyze the variables related to the pasture.

**Animal handling and grazing management**

Rotational grazing was used with two grazing strips per day (08:00 and 17:30 h) after each milking. In GRAZSUP, the target pre-grazing HM was 2500 kg DM ha$^{-1}$ (> 0 cm), while in GRAZ, the target pre-grazing HM was 2000 kg DM ha$^{-1}$ (> 0 cm). In both groups, a pasture allowance (PA) of 25 kg DM cow$^{-1}$ d$^{-1}$ (> 0 cm), divided equally for each strip, was assigned. The grazing area for each treatment was calculated based on the daily measurements of pre-grazing HM (> 0 cm) and the PA. The pasture strips were divided with electric fences in front of and behind each strip to prevent the cows from grazing over a previously grazed strip. The cows were milked twice a day (07:00 and 16:00 h). In GRAZSUP, cows were supplemented with 5.2 kg DM cow$^{-1}$ d$^{-1}$ concentrate in individual feeders in the milking parlor, whereas the GRAZ were not supplemented.

**Pasture measurements**

Pre- and post-grazing compressed height (cm) were measured in each pasture strip using a rising plate pasture meter (Jenquip, Feilding, New Zealand) to estimate HM (kg DM ha$^{-1}$; > 0 cm). Fifty measurements of the above variables were collected for each grazing strip following a zigzag pattern. The compressed height data was transformed into kg DM ha$^{-1}$ by using a specific equation for spring (Equation 1) or summer (Equation 2) pastures of southern Chile (Canseco et al., 2007):

$$Y = 100x + 400 \quad (1)$$

$$Y = 160x + 250 \quad (2)$$

where Y is HM expressed in kg DM ha$^{-1}$, and x is averaged compressed height.

Defoliation depth was estimated by subtracting pre- and post-grazing compressed height (cm). To evaluate the process of DM disappearance from the pasture, the HM was estimated using a rising plate meter, measuring HM prior the grazing event started and then every 30 min during the first 240 min of the grazing session (GS). Herbage mass disappearance rate was calculated by fitting the HM values from each treatment to the exponential model proposed by Ørskov and McDonald (1970):

$$Y = a - b\,(1 - e^{(-c \times time)}) \quad (3)$$

where a represents the initial HM (kg DM ha$^{-1}$), b is the potential HM disappearance (kg DM ha$^{-1}$), and c is the fractional disappearance rate of the HM (% h$^{-1}$).

Parameters of the model were estimated using NCSS 2019 (NCSS Statistical Software, Kaysville, Utah, USA). Instantaneous HM disappearance rates were estimated for 30, 60, 120, 180 and 240 min after the start of the GS as the first derivative of the proposed model.

**Animal measurements**

The Lifecorder PLUS device (Kenz, Suzuken, Nagoya, Japan), a single-axis accelerometer, was used to determine the AL of the cows. These devices are based on single-axis accelerometers and are placed in collars attached to the neck of cows for record the vertical movement of the head, allowing researchers to record the AL of cows during grazing events; the devices generate values ranging from 0 to 9 (where 0 denotes no activity and 9 represents maximum activity) and differentiate between movements associated with a grazing event and other activities by identifying a threshold value. Thus, AL was used as a proxy for effective grazing (Ueda et al., 2011; Delagarde and Lamberton, 2015; Piña et al., 2021). One device enclosed in a leather case (100 mm × 60 mm × 50 mm) and placed in a collar was attached to the neck of each cow. The collar was adjusted to ensure a distance of 5 cm between the collar and the neck of the animal to maximize the amount of free movement allowed by the device while the cows grazed (Delagarde and Lamberton, 2015). The devices were attached the day before the start of the experimental phase (d-1) and removed the day after the end of the measurements (d8).

Four trained observers recorded the grazing behavior by observing the cows' activity over three nonconsecutive days every week for 3 wk (three measurement periods). Grazing behavior was defined based on the following animal activities: Grazing (bite procurement, chewing between bites, and/or searching), rumination (standing or lying behavior of the animal), resting (standing or lying behavior of the animal without rumination), and other activities (social interactions, drinking, demonstration of estrus, and others). The clocks of the observers were synchronized with the internal clock of the Lifecorder PLUS device to validate the device records with those provided by visual observation. The activity of individual cows was visually observed every 10 min over the course of 240 min after the start of the GS, when animals were in the pasture. The duration of an activity was calculated by summing the duration of the activity across all 10 min intervals. Large numbers painted on the sides of the cow's aided identification.

The bite rate (bites $min^{-1}$) was recorded individually every 60 min during the first 240 min after the grazing process began. The time required to complete 30 bites was recorded and then these results were extrapolated to obtain the bite rate (bites $min^{-1}$). This measurement was made on the same days as the grazing behavior measurements.

At the end of each experimental period, the devices were removed from the collars and connected to a computer to transfer the data through a USB connection. The data were downloaded and processed using Lifestyle Coach v1.2 (Kenz, Suzuken), which offers two data processing options: The most representative AL or the average of the recorded activities in 4 s intervals over 2 min periods. The present study used the option corresponding to the average activity over 2 min periods because it was more representative of the AL of the animals (Ueda et al., 2011; Yoshitoshi et al., 2013; Delagarde and Lamberton, 2015). These data were exported into a CSV file to process the activity levels of each animal and for a later comparison with the direct observation records. Threshold values for discriminate grazing activity for each cow were calculated according to the methodology proposed by Piña et al. (2021). In both productive systems, the precision in estimating grazing time was greater than 90% (comparison between observed *vs*. predicted grazing time), with a misclassification rate less than 8%.

Absolute AL values (scale 0-9) were analyzed at five time-points of the GS (30, 60, 120, 180 and 240 min). For each of the time-points, the proportion of the AL with respect to the AL recorded at the beginning of the GS (0 min) was calculated. This variable was calculated due to the variability that AL presents per animal (Piña et al., 2021). For example, cows of the same breed, of similar size, age and productive level, may have very different absolute values of AL when grazing. Therefore, evaluating the absolute value of AL at a given time does not necessarily reflect the variations in the AL during the GS.

Herbage intake for each time interval of the GS was calculated as the difference between pre-grazing HM and HM at the end of each time interval of the GS (Macoon et al., 2003). The number of bites per cow during each time interval of the GS was calculated by multiplying the bite rate and eating time of the corresponding time interval. Thus, the bite mass of each time interval was calculated by dividing the herbage intake per time interval for the corresponding number of bites per cow.

## Statistical analyses

The variables related to the pasture characteristics, the parameters of the model of DM disappearance and the instantaneous HM disappearance rate were analyzed using a generalized linear model (NCSS 2019). The grazing strip was considered the experimental unit for the pasture measurements. Forty-two grazing strips for each treatment were evaluated (AM/PM).

The systems were non-replicated, since the main objective of the study was to analyze the variations in the AL recorded individually in each dairy cow of both production systems; however, individual cows and pasture strips were considered experimental units for either animal-related variables, as it has been followed in other whole-farm studies where animals are normally group-fed to represent whole-farm systems realistically (Horan et al., 2005; Fariña et al., 2011). Grazing behavior, bite rate, bite mass, herbage intake and AL of the cows were analyzed based on a mixed model. The fixed effect considered was production system (GRAZSUP and GRAZ), and the random effects were the individual cows and day of measurement. The latter effect was treated as a repeated measure (9 d of measurements), and the variance-covariance structure was selected per variable using the lowest Akaike information criterion (AIC) value as a criterion. Unstructured covariance, autoregressive order one and compound symmetry variance-covariance structures were tested. To assess the effect of herbage mass on the proportion of the AL with respect to the initial AL, simple linear regression models were used. Significance was declared at $P < 0.05$. Initially, the factor associated with the time of the day of grazing strip allocation (AM, PM) was included in the analysis. However, this factor was nonsignificant for any variable evaluated in the study, so it was not considered in the final analyses.

## RESULTS

### Pasture measurements and defoliation characteristics

Pre-grazing HM was greater ($P < 0.001$) in GRAZSUP compared to GRAZ (+ 750.1 kg DM $ha^{-1}$) (Table 1). There were no differences between production systems ($P > 0.05$) in post-grazing HM. Pre- and post-grazing height were higher (+12.42 cm; $P < 0.001$, and +3.92 cm; $P < 0.001$, respectively) in GRAZSUP than in GRAZ. Defoliation depth was greater ($P < 0.001$) in GRAZSUP compared to GRAZ (+8.49 cm), whereas the forage removed per cow was higher in GRAZ (+1.89 kg DM $cow^{-1}$ $d^{-1}$; $P = 0.044$) compared to GRAZSUP.

**Table 1.** Effect of dairy production system on sward measurements and defoliation characteristics. GRAZSUP: Pasture-based system with supplemented Holstein Friesian dairy cows; GRAZ: pasture-based system with non-supplemented Holstein New Zealand dairy cows; SEM: standard error of the mean.

| Sward characteristics | Production system | | SEM | P-value |
|---|---|---|---|---|
| | GRAZSUP | GRAZ | | |
| Pre-grazing herbage mass, kg DM $ha^{-1}$ | 2697.44 | 1947.33 | 96.389 | < 0.001 |
| Post-grazing herbage mass, kg DM $ha^{-1}$ | 1584.68 | 1523.50 | 46.802 | 0.248 |
| Pre-grazing height (compressed), cm | 23.02 | 10.60 | 0.471 | < 0.001 |
| Post-grazing height (compressed), cm | 11.88 | 7.96 | 0.221 | < 0.001 |
| Defoliation characteristics | | | | |
| Defoliation depth, cm | 11.13 | 2.64 | 0.333 | < 0.001 |
| Forage removed, kg DM $cow^{-1}$ $d^{-1}$ | 10.21 | 12.10 | 0.800 | 0.044 |

### Grazing behavior, bite rate, bite mass and herbage intake during the first GS

The effects of production systems on grazing behavior and DMI are shown in Table 2. The grazing time were greater in GRAZSUP than in GRAZ ($P < 0.001$) during the first 120 min of the grazing-down process, and was similar ($P > 0.05$) between groups during the last 120 min of the grazing session. Ruminating and idling times were greater ($P < 0.001$) in GRAZ than GRAZSUP during the 0-60 and 60-120 min time intervals, whereas the ruminating time in GRAZSUP was greater ($P < 0.001$) than in GRAZ during the 180-240 min time interval.

The bite rate was higher ($P < 0.05$) in GRAZSUP during the first 60 min of the GS, with an average of +3.7 bites $min^{-1}$ in GRAZSUP in relation to GRAZ. At the end of the GS, the bite rate of the GRAZ cows was higher ($P = 0.003$) compared with the GRAZSUP cows (+4.7 bites $min^{-1}$). During the first 60 min of the GS, the bite mass was significantly higher (+0.39 g DM; $P = 0.009$) in GRAZSUP compared with GRAZ, whereas in 60-120 min time interval, the bite mass was higher ($P = 0.006$) in GRAZ compared with GRAZSUP. There was no difference ($P > 0.05$) of the bite mass in the 120-180 min time interval. Herbage intake was higher (+1.69 kg DM $cow^{-1}$; $P = 0.002$) in GRAZSUP compared with GRAZ during the first 60 min of the GS, whereas the herbage intake during the 60-120 min and 120-180 min time intervals was higher ($P < 0.01$) in GRAZ than in GRAZSUP.

**Table 2.** Grazing behavior, bite rate, bite mass and herbage intake of dairy cows in two dairy production systems during the first grazing session. GRAZSUP: Pasture-based system with supplemented Holstein Friesian dairy cows; GRAZ: pasture-based system with non-supplemented Holstein New Zealand dairy cows; SEM: standard error of the mean. [1]The comparison between production systems was made within each time interval (same row).

| Item | Time interval, min | Production system | | SEM | P-value[1] |
|---|---|---|---|---|---|
| | | GRAZSUP | GRAZ | | |
| Grazing time, min | 0-60 | 59.54 | 53.39 | 0.521 | < 0.001 |
| | 60-120 | 52.01 | 39.40 | 1.514 | < 0.001 |
| | 120-180 | 30.08 | 30.29 | 1.570 | 0.906 |
| | 180-240 | 22.95 | 27.73 | 2.340 | 0.061 |
| Ruminating time, min | 0-60 | 0.08 | 3.45 | 0.346 | < 0.001 |
| | 60-120 | 3.87 | 13.15 | 1.146 | < 0.001 |
| | 120-180 | 18.31 | 16.96 | 1.426 | 0.404 |
| | 180-240 | 22.63 | 14.04 | 2.265 | < 0.001 |
| Idling time, min | 0-60 | 0.12 | 2.08 | 0.273 | < 0.001 |
| | 60-120 | 3.15 | 6.36 | 0.792 | < 0.001 |
| | 120-180 | 9.11 | 10.35 | 1.142 | 0.339 |
| | 180-240 | 9.60 | 15.00 | 1.823 | 0.006 |
| Bite rate, bites $min^{-1}$ | 0 | 67.42 | 63.44 | 0.688 | < 0.001 |
| | 60 | 65.05 | 61.55 | 0.869 | 0.003 |
| | 120 | 59.74 | 59.78 | 1.062 | 0.981 |
| | 180 | 53.87 | 58.56 | 0.976 | 0.003 |
| Bite mass, g DM | 0-60 | 0.956 | 0.562 | 0.105 | 0.009 |
| | 60-120 | 0.281 | 0.709 | 0.095 | 0.006 |
| | 120-180 | 0.497 | 0.780 | 0.097 | 0.214 |
| Herbage intake, kg DM $cow^{-1}$ | 0-60 | 3.576 | 1.886 | 0.387 | 0.002 |
| | 60-120 | 0.997 | 1.673 | 0.223 | 0.003 |
| | 120-180 | 0.713 | 1.458 | 0.184 | 0.005 |

## Herbage disappearance dynamics

The values of the parameters a and b of the herbage mass disappearance model (Table 3) differed between treatments ($P < 0.001$), while there was no effect ($P = 0.094$) for the parameter c. The instantaneous rate of disappearance of DM was higher ($P < 0.05$) in GRAZSUP than in GRAZ at 30, 60 and 120 min of the grazing-down process, while at 180 and 240 min, there were no differences between treatments ($P > 0.05$).

**Table 3.** Coefficients of the model used to characterize the grazing-down process and herbage disappearance rate in a pasture grazed for dairy cows in two production systems. GRAZSUP: Pasture-based system with supplemented Holstein Friesian dairy cows; GRAZ: pasture-based system with non-supplemented Holstein New Zealand dairy cows; SEM: standard error of the mean; a: pre grazing herbage mass; b: potential herbage mass disappearance; c: fractional disappearance rate of herbage mass (% $h^{-1}$).

| Item | Production system | | | |
|---|---|---|---|---|
| | GRAZSUP | GRAZ | SEM | P-value |
| a | 2668.3 | 2015.9 | 95.07 | < 0.001 |
| b | 1287.0 | 529.8 | 106.42 | < 0.001 |
| c | 1.2565 | 0.5056 | 0.36 | 0.094 |
| Herbage disappearance rate, kg DM $ha^{-1}$ $h^{-1}$ | | | | |
| At time 0.5 (30 min) | 630.73 | 196.33 | 70.59 | < 0.001 |
| At time 1 (60 min) | 349.55 | 148.71 | 32.84 | < 0.001 |
| At time 2 (120 min) | 153.34 | 88.66 | 25.14 | 0.041 |
| At time 3 (180 min) | 82.59 | 55.33 | 19.80 | 0.263 |
| At time 4 (240 min) | 49.28 | 35.89 | 15.72 | 0.485 |

**Activity level (AL) recorded from Lifecorder PLUS, and proportion of AL with respect to initial AL**

The effects of the production systems on the AL recorded from Lifecorder PLUS are reported in Table 4. The activity level at 30 min of the grazing-down process was higher (+1.3; P < 0.001) in GRAZ compared with GRAZSUP, while at 60, 120, 180 and 240 min there were no differences (P > 0.05) between treatments. When the AL is evaluated as the proportion of the activity recorded at a time-point of the grazing-down process with respect to the initial AL, there were no differences (P > 0.05) in each of the times evaluated.

**Table 4.** Activity level (AL) and proportion of the activity with respect to the initial AL recorded for the Lifecorder PLUS in the grazing down process of a pasture grazed for dairy cows in two dairy production systems. GRAZSUP: Pasture-based system with supplemented Holstein Friesian dairy cows; GRAZ: pasture-based system with non-supplemented Holstein New Zealand dairy cows; SEM: standard error of the mean.

| Item | Production system | | | |
|---|---|---|---|---|
| | GRAZSUP | GRAZ | SEM | P-value |
| Activity level (AL, scale 0-9) | | | | |
| At time 0.5 (30 min) | 2.86 | 4.16 | 0.146 | < 0.001 |
| At time 1 (60 min) | 2.45 | 3.27 | 0.318 | 0.166 |
| At time 2 (120 min) | 1.15 | 1.99 | 0.322 | 0.162 |
| At time 3 (180 min) | 0.85 | 1.30 | 0.325 | 0.429 |
| At time 4 (240 min) | 0.03 | 0.63 | 0.403 | 0.411 |
| Proportion of AL with respect to initial AL | | | | |
| At time 0.5 (30 min) | 0.90 | 0.93 | 0.022 | 0.488 |
| At time 1 (60 min) | 0.76 | 0.71 | 0.060 | 0.676 |
| At time 2 (120 min) | 0.34 | 0.44 | 0.076 | 0.486 |
| At time 3 (180 min) | 0.29 | 0.28 | 0.083 | 0.884 |
| At time 4 (240 min) | 0.01 | 0.13 | 0.077 | 0.320 |

A significant relationship (P < 0.05) was found between herbage mass and the proportion of the AL with respect to the initial AL (Figure 1), during the period of access to the pasture. In this way, it was observed a reduction of 0.0011 points in the proportion of AL with respect to the initial AL per each kilogram of decrease in herbage mass ($R^2$ = 0.85) in GRAZSUP (Figure 1a), whereas in GRAZ, there is a reduction of 0.0023 points in the proportion of AL with respect to the initial AL ($R^2$ = 0.98) due to the reduction in 1 kg DM herbage mass (Figure 1b).

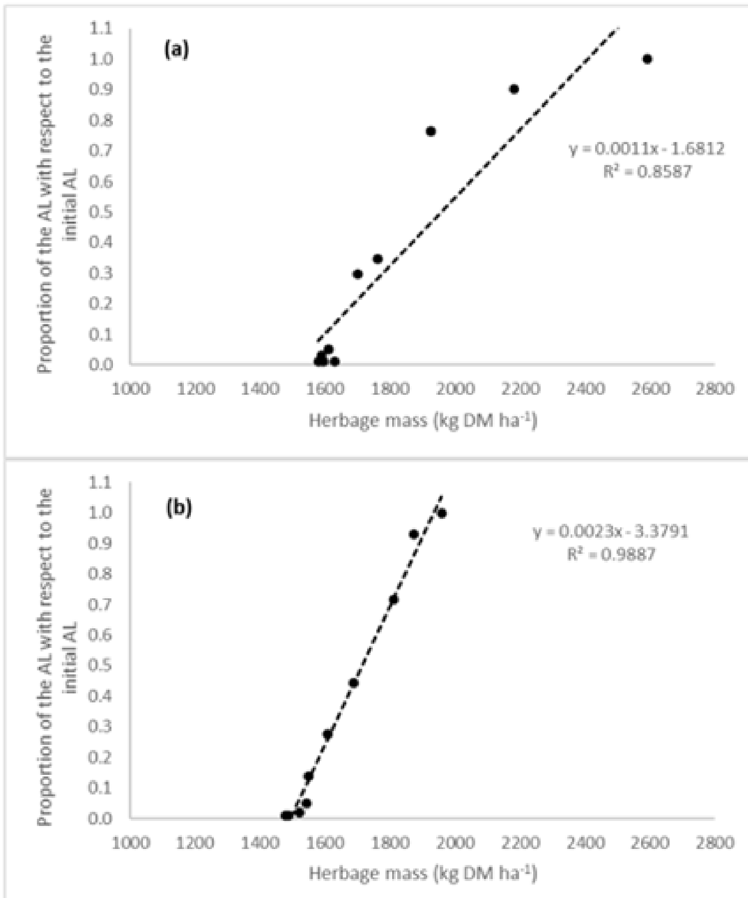


**Figure 1.** Relation between herbage mass and proportion of the activity level (AL) with respect to the initial AL, recorded for the Lifecorder PLUS during the period of access to the pasture in the grazing down process of a pasture in GRAZSUP (a) and GRAZ (b) production systems. GRAZSUP: Pasture-based system with supplemented Holstein Friesian dairy cows; GRAZ: pasture-based system with non-supplemented Holstein New Zealand dairy cows.

## DISCUSSION

**Grazing management and defoliation characteristics according to the production system**

The results of this study reflect the feed management of the pasture-based dairy systems in southern Chile (Pulido et al., 2010; Delgadillo et al., 2016). Pasture-based dairy systems use a high proportion of grazed pasture in the cows' diet during the spring and summer (Dillon et al., 2005), with varying levels of concentrate supplementation depending on the productive performance of the cows (Fariña et al., 2011; Brady et al., 2022).

In production systems with high yielding dairy cows, it has been observed that one of the main limitations to achieve high levels of milk production in pasture-based systems is the low DMI from the pasture (Pulido and Leaver, 2001; Bargo et al., 2003), which would limit energy intake. Therefore, it is usual to use concentrate supplementation to increase DM and energy intake (McCarthy et al., 2007b).

Production systems that use Holstein Friesian as the main strain are characterized by using higher levels of concentrate supplementation during the entire lactation and lower stocking rates than the production systems based on the use of the New Zealand Holstein strain (McCarthy et al., 2007a), whose objective is to increase the amount of pasture grazed per hectare (Shalloo et al., 2004; Kennedy et al., 2021), using higher stocking rates and minimal concentrate supplementation. Accordingly, the production system and the season of the year in which the measurements were made had a significant influence on the defoliation process of the pasture.

In the case of GRAZSUP system, the measurements were made in the spring, so the availability of pre-grazing herbage mass (HM) is greater than in summer, which results in a greater defoliation depth and a smaller area assigned per cow, in relation to the management carried out in GRAZ system, in which the measurements were made in summer. The lower amount of pasture intake in GRAZSUP system is related to concentrate intake in this group of cows, which is consistent with the results of Bargo et al. (2002; 2003).

**Grazing behavior and herbage disappearance during the first grazing session**

During the first 120 min of the grazing session, the grazing process of the cows in GRAZSUP was characterized by a longer grazing time, a higher bite rate and a greater bite size (Piña et al., 2020), caused by a greater HM and a bigger jaw, which implied a higher forage intake in relation to GRAZ, which agrees with the results of Horan et al. (2007) and Sheahan et al. (2011). Furthermore, according to Pulido and Leaver (2001), an increase in grazing time is associated with higher nutrient and energy demand of HF cows, resulting from a higher milk yield. In each grazing strip, cows of the GRAZSUP system consumed 44.8% of the daily DMI in the first 120 min of the grazing session, while cows in the GRAZ system consumed 29.4% of the daily DMI, which would indicate that cows of the GRAZSUP system have a more intense and concentrated grazing process in the first hours after the beginning of the grazing session, while cows of the GRAZ system realize a more stable grazing process through the first grazing session, which can be observed in the dynamics of DM disappearance of both groups (Table 3). According to McCarthy et al. (2007b), this would be due to a longer handling time and lower biting rate observed in GRAZ cows in relation to GRAZSUP cows due to a lower HM, which they compensate with a greater daily grazing time (Boval and Sauvant, 2021). Furthermore, summer pastures have a higher fiber content (Keim et al., 2014; Pérez-Prieto et al., 2018) which causes a slower DM degradation rate, which could influence the intake rate in GRAZ cows.

During the first 120 min of the GS, DM disappearance was higher in the GRAZSUP system compared to GRAZ, which is consistent with the longer grazing time and higher intake rate of this group of cows (Table 3). After 120 min, DM disappearance tends to be similar between both grazing groups, as a result of the greater difficulty in obtaining a grazing bite from lower strata of the pasture, which concurs with the findings reported by Amaral et al. (2012) and Wims et al. (2014).

If both grazing strips are considered, at the end of the first 240 min of the grazing session, the herbage disappearance in GRAZSUP represented a value close to 100% of the total daily DMI of dairy cows, while in GRAZ it represented 83% of the total daily DMI (Tables 1 and 2). While it is true that, during the use of the morning strip, dairy cows had an additional 3 h of grazing available after the first 240 min of evaluations and an additional 8.5 h of grazing during the afternoon strip, the DMI and activity level were very low in those periods, which can be observed in Figure 1, by analyzing the relationship between HM values close to post-grazing herbage mass and proportional activity levels. In a strip-based grazing system, grazing time and DMI of the animals tend to increase in the first hours after the pasture allocation, as a result of behavioral modifications associated with maximizing nutrient and energy intake (Gregorini, 2012). Thus, dairy cows would adapt their intake behavior in relation to the number of daily grazing-strips that will be delivered.

**Variation of activity level of dairy cows during the grazing session**

Activity level registered in the GRAZ system during the first 30 min of the grazing session was higher than in the GRAZSUP system, which could be due to a greater movement of the head made by HNZ strain in each bite. According to Tharmaraj et al. (2003), the bite fracture force (force required to break a portion of the pasture) increases as HM is lower, which would cause a greater movement of the accelerometer in GRAZ cows which grazed a pasture with lower HM. After the first 30 min, AL recorded by the accelerometer was similar between treatments due to the reduction in grazing activity and biting rate, caused by the decrease in HM due to the grazing-down process in both groups (Piña et al., 2021).

We found no differences between groups in the proportion of AL in relation to the initial AL during the entire grazing session and the level of reduction in AL between the different time points evaluated was similar in each group of cows. It was observed that, at the time of reaching HM values close to 1500 kg DM $ha^{-1}$, which occurred at minute 180 from the beginning of the grazing-down process, AL recorded by the Lifecorder PLUS were 71% and 72% lower than the values recorded at the beginning of the grazing session, for GRAZSUP and GRAZ, respectively (Table 4).

It is worth highlighting the similarity of the results obtained when evaluating two different strains and production systems, in two contrasting seasons of the year and with a different feeding management. The device used has the ability to detect differences in grazing patterns associated with the structural characteristics of the pasture (Yoshitoshi et al., 2013; Piña et al., 2021) and with the ingestive behavior of dairy cows, so it is expected that the absolute value of the activity level would be different (Piña et al., 2021). Nevertheless, it is a useful tool for detecting changes in grazing patterns within the same group of cows during the grazing session, which is reflected in the results of the proportional variation of AL during the grazing-down process (Table 4 and Figure 1).

The variation in AL recorded during the grazing session due to the grazing patterns of the cows, may be due to changes in the structural and nutritive characteristics of the pasture during the grazing session and, therefore, in the alterations in the grazing behavior of the cows (Ueda et al., 2011; Delagarde and Lamberton, 2015), or by the end of the grazing cycle and the beginning of the rumination cycle, associated with the ruminal filling level and fiber intake (Taweel et al., 2004). In both cases, having an indicator of the AL of the cows that reflects their grazing behavior could be extremely useful for decision-making in grazing management. Devices that are capable of delivering this information remotely and in real-time, would allow them to be used with other technologies associated with the automation of grazing management in dairy cows (for example, GPS devices and virtual fences), which would increase grazing efficiency and reduce the labor requirements associated with grazing management.

## CONCLUSIONS

The results of the study demonstrated that the activity level recorded by the Lifecorder PLUS in dairy cows was significantly affected by the changes suffered by the pasture and the cows during the grazing-down process, reflecting the modifications in grazing behavior of dairy cows across the grazing session. The similarity in the results obtained in two contrasting dairy production systems demonstrated that the activity level of grazing dairy cows could be integrated into a decision-making tool for grazing management that allows automating some labors associated with pasture allocation in grazing dairy systems.

## Author contribution

Conceptualization: L.F.P., O.A.B., H.G.V. Methodology: L.F.P., O.A.B., J.P.K., R.G.P., H.G.V. Software: L.F.P., F.R., C.A. Validation: L.F.P., F.R., C.A. Formal analysis: L.F.P. Investigation: L.F.P., F.R., C.A. Resources: L.F.P., O.A.B., H.G.V. Data curation: L.F.P., F.R., C.A. Writing original draft preparation: L.F.P. Writing review and editing: L.F.P., O.A.B., J.P.K., R.G.P., H.G.V. Visualization: L.F.P. Supervision: O.A.B., J.P.K., R.G.P., H.G.V., L.F.P. Project administration: O.A.B., R.G.P., L.F.P., H.G.V. Funding acquisition: L.F.P., O.A.B., H.G.V. All co-authors reviewed the final version and approved the manuscript before submission.

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