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On-animal sensors: measuring grazing cattle behaviour under two different supplement strategies

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Abstract

Protein supplements are a common approach to address nutrient deficiencies in rangeland cattle. On-animal sensors have emerged as an alternative for measuring individual cattle behaviour, including supplement intake, in near real-time without human intervention. This study aimed to study the combination of on-animal sensors to monitor behavioural changes in response to varying levels of individual supplement consumption.

Fourteen Droughtmaster heifers were fitted with a wireless ear tag (WelfareTag™ HerdDogg), GPS collar (i-gotU GT-600), and rumen bolus (SmaXtec® Classic Bolus). They co-grazed a 10-ha paddock from 20/9/22 to 13/12/22. In two consecutive periods, they were offered different supplementary high-protein diets, expected to vary in palatability. During period one (days 1-42), heifers received 300 g/d of a low-intake supplement (26% CP, 5% Urea), and during period two (days 43-85), they received 1000 g/d of a high-intake supplement (30% CP, 4% Urea). Data were analysed using R (version 4.3.1) and RStudio with a linear mixed-effects model ('lmer'), each parameter was considered individually.

During period 2, heifers spent 1.7 times more time at the feed trough than in period 1 ($p<0.001$), suggesting increased supplement consumption. Grazing activity was not significantly higher in period 1 than in period 2 ($p<0.1$). Resting time in period 1 decreased ($p<0.1$) but travelling times increased ($p<0.01$). Rumen temperature and rumination index were lower in period 1 ($p<0.05$, $p>0.1$), while oestrus index was higher in period 1 compared to period 2 ($p<0.001$). Counts of water-drinking events were higher in period 2 ($p<0.001$).

In conclusion, behavioural differences were detected by on-animal sensors associated with greater supplement intake. The adoption of sensors for continuous monitoring enhances nutritional, grazing, and reproductive management in extensive rangelands, supporting better decision-making about target supplement intake and improving grazing behaviour and pasture utilisation.

Introduction

The Australian beef production operations are predominantly pasture-based, with grazing cattle facing challenges such as fluctuating pasture quality and quantity during the dry season, mineral deficiencies in the soil, and unpredictable rainfall that affects forage availability. To address these challenges and minimize production losses, supplemental feeds are often provided during the dry season to supply essential proteins, minerals, and energy (Bowman & Sowell, 1997). However, the effectiveness of supplementation relies on animals consuming the target amounts. In recent years, precision livestock management has emerged, allowing producers to monitor the health, welfare, and productivity of animals in near-real-time. On-animal sensors are central to this approach, enabling continuous, remote monitoring of livestock behaviour 24/7. These sensors, attached directly to the animal, can record a range of behaviours, offering valuable insights for managing extensive cattle systems. This study aims to integrate three types of on-animal sensors—a wireless ear tag, a rumen bolus, and a GPS tracking collar—to monitor behavioural changes in grazing cattle in response to varying levels of individual supplement intake. We hypothesize that these sensors can detect behavioural adaptations to different supplementation levels.

Methods

The study was conducted from September 20 to December 13, 2022, at the University of Queensland, Gatton, Australia. Fourteen Droughtmaster heifers, aged 11-13 months (average weight: 268 ± 32.7 kg, range: 194-320 kg), were allocated to a 10.11 ha paddock with unimproved pasture African star grass *(Cynodon nlemfuensis Vanderyst)* at 85% coverage and Queensland blue grass (*Bothriochloa pertusa*) and provided mineral and protein supplements for 12 weeks. The experiment was divided into two periods. During period 1 (days 1-42), heifers were offered a low-intake supplement (target: 300 g/head/day) containing 12% crude protein, 5% urea, and 5 MJ/kg energy (PBA Feeds, Toowoomba, Qld). In period 2 (days 43-85), they received a high-intake supplement (target: 1000 g/head/day) with 19% crude protein, 4% urea, and 8 MJ/kg energy (PBA Feeds, Toowoomba, Qld).

Each heifer was fitted with three on-animal sensors: 1) Wireless ear tags (WelfareTag™, HerdDogg) with Bluetooth technology recorded the animal's presence and the received signal strength indication (RSSI). A threshold of ≥ -50 dBm was used to predict time spent at the feed trough, based on prior studies(reference if appropriate); 2) GPS tracking collars (i-gotU GT-600) recorded the heifers' positions at 10-second intervals to monitor grazing patterns and classify heifers' activity; and 3) Rumen boluses (SmaXtec® Classic) recorded temperature, oestrus index, rumination rate, and water intake, with a temperature drop below 38°C indicating drinking events. The classification of cattle activity into three different categories – grazing, resting, and travelling – was based on the criteria established by Augustine and Derner (2013). Data were collected over 85 days. A linear mixed-effects model ('lmer') in R (version 4.3.1) was used for statistical analysis of the longitudinal data with repeated measures.

Results

Wireless ear tag

During period 2, heifers spent an average of 8 minutes at the feed trough, compared to 4.5 minutes in period 1, representing a 1.7-fold increase ($p < 0.001$). This indicates a significant increase in supplement consumption during the second period (Table 1).

GPS tracking collar

Grazing activity was higher in period 1 (21.37%) than in period 2 (17.37%), but this reduction in grazing time was not statistically significant (Table 1, $p > 0.1$). When comparing the two different periods, it was found that the resting time in period 1 (69.18%) was lower than in comparison period 2 (77.62%), however

that difference was not significantly different (Table 1, $p > 0.1$). Travelling time was increased in period 2 (3.57%) compared to period 1 (2.85%), this difference was significantly different (Table 1, $p < 0.01$). Additionally, there was a statistical difference in travel time between the two periods ($p < 0.01$), with heifers in period 2 travelling 0.54% more than during period 1.

Rumen bolus

The results showed that there was a significant (Table 1, $p < 0.05$) increase in the heifers' reticulo-rumen temperature by 0.12°C in period 2 compared to period 1. During period 1, the average reticulo-rumen temperature was 39.08°C, while in period 2 it was 39.17°C. The rumination index of heifers showed no significant difference in response to the two different supplement target intake (Table 1, $p > 0.1$). Although the average rumination index in period 1 was 26,6540 and in period 2 it was 27,734, it was found that the increase between the two periods was not statistically significant ($p > 0.1$). The oestrus index had a significant influence on the two different periods. The results showed that heat index increased significantly (Table 1, $p < 0.001$) from period 1 to period 2. In period 1, the average oestrus indicator was 3.19 units, while in period 2 it decreased to 2.35 units. The heifers in period 1 had a higher oestrus index on the day of oestrus than in period 2. In Period 2, heifers under the higher supplement intake had a lower average of oestrus index. The results for the cumulative number of water-drinking events per day showed a significant increase of 1.64 in period 2 compared to period 1 (Table 1, $p < 0.001$). During period 1, the average cumulative water drinking events per day was 3.17, while in period 2 it increased to 5.23.

Table 1 contains detailed data on the difference in measured behaviours: time spent at the feed trough, grazing time, resting time, travelling, rumen temperature, rumination index, heat index and counts of water drinking events, between the two periods.

Table 1 Difference in measured behaviours using on-animal sensors between the 2 periods.

Behaviours measured	Period		SEM	P-value
	1	2		
Time spent at the feed trough (min)	4.5	8.0	0.46	<0.001
Grazing time (%)	20.37	17.37	1.07	0.08
Resting time (%)	69.18	77.62	1.05	0.09
Travelling time (%)	3.06	3.60	0.09	0.002
Rumen temperature (°C)	39.08	39.17	0.02	0.015
Rumination index[1]	26654	27734	721	0.29
Oestrus index[2]	3.19	2.35	0.15	<0.001
Counts of water-drinking events	3.17	5.23	0.27	<0.001

[1]Measures rumination times every 10 minutes. [2]Dectects heifer on oestrus based on behaviour changes.

Discussion

Supplemental feeding is a common strategy to enhance the performance of grazing beef cattle. However, traditional herd-based monitoring of supplement intake often overlooks individual variability in consumption and may not account for animals that do not consume the supplement (Bowman & Sowell, 1997). Precision livestock management can provide continuous near-real-time monitoring on an individual animal basis, rather than via herd-based information (Aquilani et al., 2022). In this study we combined the use of three on-animal sensors to continuously monitor 14 heifers, revealing significant insights into cattle behaviour and supplement intake.

The wireless ear tag recorded the predicted time spent at the feed trough, with cumulative counts of RSSI ≥ -50 dBm indicating that time at the trough increased by 1.8 times during the second period, which featured a more palatable supplement. This second supplement had nearly double the metabolisable energy (8 MJ/kg vs. 5 MJ/kg) and a higher protein content (30% vs. 26%), which likely contributed to its enhanced palatability and voluntary intake (Launchbaugh et al., 1997; McDowell, 1996). Previous research (Imaz et al., 2020, p. 8; Nkrumah et al., 2007, p. 2388; Oliveira et al., 2018, p. 634) has demonstrated that time spent at the feed trough has a strong positive correlation with feed intake. Our results are consistent with the previous work cited above and show that as the palatability of the supplement increases, the voluntary intake and predicted time spent at the feed trough also increase.

Our results showed that increased time at the feed trough corresponded with a reduction in grazing time, particularly during the second period, when the supplement provided an intake target of 1 kg/day per head. This decrease in grazing time is consistent with literature indicating that high-protein supplements can reduce grazing activity (Bargo et al., 2003). This effect is likely due to the substitution effect, where providing a higher amount of supplement reduces pasture intake and, consequently, grazing time. Bargo et al. (2003) reported that for each kilogram of supplement offered to grazing dairy cows, there was a reduction of 12 minutes in grazing activity.

The heifers averaged 72.44% and 77.62% resting time during periods 1 and 2, respectively, supporting previous observations that grazing cattle often exhibit significant inactivity (Swain et al., 2008). Additionally, we noted a statistically significant increase in travel time during the hotter second period, likely due to the heifers seeking shade, which was located 400 m from the feed trough. Period 2 was, on average, 4°C hotter than period 1, with maximum temperature ranging from 21.3°C to 37.6°C. The heifers displayed higher reticulo-rumen temperatures during period 2 (39.18°C) compared to period 1 (39.06°C). This increase may result from the animals' inability to dissipate sufficient metabolic heat (Becker et al., 2020) and the higher energy content in the feed, which also contributed to the increased rumen temperature in period 2. Kurihara (1996) also observed an increase in body temperature and respiration rate in dairy cows when comparing a low to a high-quality diet.

During the trial, the heifers were in oestrus for five days out of 50 in period 1 and two days out of 35 in period 2. Notably, predicted time spent at the feed trough decreased during oestrus ($p < 0.001$), corroborating findings by Reith et al. (2014) that report a 14.6% reduction in intake on oestrus days. The cumulative number of water drinking events also significantly increased by 1.64 times in period 2 ($p < 0.001$), suggesting that the heifers were compensating for heat stress by increasing water intake. Ahlberg et al. (2018) found that the water intake in feedlot steers increased when they were exposed to temperatures above 28.06°C. Weather conditions, particularly maximum temperature, significantly impacted the time spent seeking shade. The heifers spent an average of 18.42% of their time in the treed area during period 2, compared to only 6.18% in period 1.

In summary, this study confirmed the efficacy of on-animal sensors in monitoring individual cattle behaviours that affect supplement intake. The combined use of these technologies facilitated a nuanced understanding of how supplement consumption, grazing time, and environmental factors interact. Future research with larger herds and varying supplement types is recommended to further validate the applicability of on-animal sensors in pasture-based systems.

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