

Behaviour of Aubrac Cows at Pasture in Relation to Parity, Temperature, and Precipitation Monitored with a Sensor System

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Cattle behaviour is strongly influenced by physiological status and environmental conditions, particularly ambient temperature, while precipitation has received less attention in pasture-based systems. This study investigated parity-dependent behavioural responses of grazing Aubrac cows to ambient temperature and precipitation using an ear-tag sensor monitoring system. A total of 26 cows were monitored from May to August 2025 with the DataMars system, recording feeding, ruminating, standing, and resting times. Cows were grouped by parity (0, 1, 2), and behavioural data were expressed as average hourly durations per day. Ambient temperature and precipitation data were obtained from a local meteorological station. Days were classified as thermoneutral ($< 20\text{ }^{\circ}\text{C}$) or warm ($\geq 20\text{ }^{\circ}\text{C}$), based on literature. Parity significantly influenced all behavioural traits, with small effects on feeding and standing and moderate effects on ruminating and resting. Higher temperatures were associated with reduced feeding and ruminating, increased standing, and decreased resting across parity groups. Precipitation showed no detectable effect on feeding, but correlated with longer ruminating and resting and shorter standing, particularly on warm days. These effects were generally small to moderate and largely absent under cooler conditions. The results indicate that ambient temperature is the primary environmental driver of behavioural change in grazing Aubrac cows, while precipitation acts as a secondary modifier during warm periods. Behavioural indicators such as rumination, resting, and standing are sensitive to weather-related strain and may provide valuable tools for welfare monitoring in pasture-based cattle systems.

Keywords: parity, temperature, behaviour, precipitation, sensor systems

1 Introduction

Cattle behaviour can be influenced by multiple factors, particularly the animal's physiological status and environmental conditions, with ambient temperature playing a key role. It was hypothesised that increasing ambient temperature reduces the time spent feeding and ruminating in Aubrac cows, while increasing standing time and decreasing resting time. In addition, we aimed to evaluate the effect of precipitation on selected behavioural traits in grazing cattle, as farm management and research typically focus on temperature-humidity index (THI), whereas rainfall has been less frequently addressed. Therefore, this study aimed to determine whether ambient temperature and/or precipitation affect the behaviour of Aubrac cows

on a selected farm and whether these responses differ according to parity.

Due to greater exposure of animals and their resources to weather conditions in more open housing systems, the thermal comfort of cows and their ability to thermoregulate play a major role in assessing challenges across different functional areas. Thermal comfort is affected by various environmental parameters, including air temperature, humidity, velocity, solar radiation, and precipitation (West, 2003; Shephard and Maloney, 2023). Animal heat tolerance also differs with individual characteristics – such as breed, age, milk yield, body condition, or coat colour – and with how these traits interact with environmental conditions (Kadzere et al., 2002). Overall, adult cattle exhibit a fairly broad

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thermoneutral range; however, they generally regulate body temperature more effectively in cold environments than under heat stress (Hemsworth et al., 1995).

Dairy cows managed outdoors may seek protection from windy and rainy conditions (Schütz et al., 2010), and will spend the majority of their time under shelter when provided during winter (Cartes et al., 2021). This is likely related to the cow's motivation to access comfortable, dry lying surfaces, which can be limited in winter conditions. For example, in both housed and pastured cattle, cows prefer to lie on dry, well-bedded, clean surfaces (Schütz et al., 2010; Cartes et al., 2021). The amount of time that cows spend lying is an important welfare indicator. Longer lying times often suggest more comfortable lying surfaces (e.g., mattresses vs. concrete flooring; Haley et al., 2000). If lying time is compromised, biological health and functioning can be negatively affected. For example, shorter lying times can be a risk factor for lameness in grazing cows (Sepúlveda-Varas et al., 2018, Hendriks et al., 2020) and can affect function of the pituitary-adrenal axis, leading to increased chronic stress (Fisher et al., 2002). Therefore, identifying how outdoor conditions influence lying time is important for interpreting welfare under pasture-based management.

The behaviour of cows during heat stress conditions was also studied by previous researchers. For example, according to Hoffmann et al. (2020), as a reaction to heat stress, cows show a variety of behavioural changes, such as changes in eating and activity. Further, Holinger et al. (2024) suggest that changes in behaviour could provide a valuable metric to evaluate heat stress effects. Several behaviours are considered signs of heat stress, such as prolonged standing, shade-seeking, and decreased activity, mobility, and lying period (Allen et al., 2015; Schütz et al., 2008). Furthermore, the feeding behaviour of cows changes under heat stress, with reduced feed intake to limit heat produced from digestion by adjusting feeding time and the size and length of the meal. At the same time, they increase water consumption and likely remain near the water trough (Baccouri et al., 2025; Pontiggia et al., 2024).

Cows employ two main strategies to improve respiratory efficiency and optimize body surface area: decreasing the duration of resting and extending the period of remaining upright. These actions help facilitate both sensible and insensible heat loss. This helps reduce heat transfer from warm surfaces when lying down (Anderson et al., 2013). Furthermore, the feeding behaviour of cows changes under heat stress, with reduced feed intake to limit heat produced from digestion by adjusting feeding time and the size and the length of the meal. At the same time, they increase water consumption and likely remain

near the water trough (Ammer et al., 2018; Pontiggia et al., 2024).

The study aimed to determine whether and how ambient temperature and precipitation affect the behavior of Aubrac cows at pasture – specifically, feeding, rumination, standing, and lying times – and whether these responses differ according to parity. We tested the hypothesis that higher temperatures shorten feeding and rumination, prolong standing, and shorten lying; at the same time, we assess the extent to which precipitation modifies these behaviors

2 Material and Methods

2.1 Farm and Animals

The study was conducted on a selected beef cattle farm with Aubrac cows. A total of 26 cows of this breed were included in the study and classified according to parity into heifers (parity 0; $n = 19$), cows in first lactation (parity 1; $n = 4$), and cows in second lactation (parity 2; $n = 3$). All animals were managed under uniform housing and management conditions throughout the monitoring period.

The pasture consisted of permanent grassland dominated by species of the genera *Lolium*, *Festuca*, and *Trifolium*. During the monitoring period, feed intake was primarily based on grazing. In addition, one bale of hay was supplied daily in a feeder. A trough for concentrate feed was available with sufficient feeding space for all animals, and each cow received approximately 1 kg of ground corn grain per day as a supplementary feed.

Indicative nutritional values of the pasture (based on routine seasonal farm analyses) were as follows: neutral detergent fibre (NDF) approximately 45–55% of dry matter, acid detergent fibre (ADF) approximately 25–35% of dry matter, crude fibre 22–28% of dry matter, starch < 5% of dry matter, and crude protein 14–18% of dry matter depending on vegetation stage. These values correspond to typical Central European pasture production and provide sufficient structural fibre to support rumination.

Animals were managed in an extensive 24-hour pasture-based system throughout the entire monitoring period and were not housed indoors at any time during the study. They had access to natural shade provided by trees and to a fixed shelter (12 × 25 m) offering protection against rain and direct solar radiation. Stocking density was low. The total fenced pasture area was 12 ha, corresponding to approximately 0.46 ha per animal, which is equivalent to less than 1 livestock unit per hectare. This low stocking density minimized social competition and ensured

sufficient grazing space. No signs of marked competition at feeding sites were observed during the study period. Two automatic waterers ensured *ad libitum* access to fresh water. No bedding material was used, as cows rested directly on the permanent grass sward. These conditions ensured that behavioural responses were not limited by space, feeding access, or water availability.

The ear-mounted sensor records triaxial acceleration data at a sampling frequency of 2,4 GHz. Raw acceleration data are processed using a proprietary behavioural classification algorithm based on validated motion patterns. According to manufacturer validation studies comparing sensor output with continuous visual observations, behaviour classification accuracy exceeds 90% for rumination and 85–95% for feeding and activity behaviours. System validation was performed under controlled farm conditions using synchronized direct behavioural scoring.

2.2 Behavioural Data Collection

Animal behaviour was monitored from 16 May to 31 August 2025 using the DataMars monitoring system (Datamars, Switzerland). Each animal was equipped with an ear-mounted sensor that continuously recorded the duration of individual behavioural activities.

The system is based on an ear-tag sensor equipped with an integrated 3-axis accelerometer and proprietary algorithmic classification of behaviours (feeding, ruminating, standing, resting). The sensor continuously records motion data; raw acceleration signals are internally processed and aggregated into minute-level intervals, which are subsequently summarized into hourly durations of each behavioural activity.

Each day represents 24 hourly aggregated values per animal and per behavioural variable. With 26 animals monitored over 108 days, this corresponds to approximately 67,392 hourly records per behavioural variable before data cleaning. For statistical analyses, hourly data were recalculated into average hourly durations per day (h/day). Each behavioural variable, therefore, represents the sum of 60 one-minute classified intervals per hour and 1,440 minute-level observations per day per animal.

Data were transmitted wirelessly via ISM-band radio frequency to a central farm gateway functioning as an IoT bridge, which uploaded the data via the mobile network to a secure cloud storage platform provided by the manufacturer. Data were accessible through the manufacturer's web interface and exported in CSV format for further statistical processing. Behaviour classification, particularly rumination and activity detection, was validated by the manufacturer through

comparison with simultaneous visual observations according to internal validation protocols.

The following behaviours were evaluated:

- feeding,
- ruminating,
- standing,
- resting.

The recorded data were processed and expressed as average hourly durations per day, allowing comparison of behavioural patterns among animals and parity groups.

2.3 Meteorological Data and Temperature Classification

The experimental farm is located in Babindol, Slovakia (Nitra district). The exact geographical coordinates of the farm are approximately 48° 17' N, 18° 09' E, at an altitude of about 180 m above sea level. Climatic data were obtained from the meteorological station in Klasov, Slovakia, which is situated approximately 2 km from the farm. The meteorological station is located at approximately 48° 21' N, 18° 11' E, at an altitude of about 175 m above sea level. The region belongs to a warm and moderately dry climatic area with mild winters and warm summers. The average annual air temperature is approximately 10–11 °C, and the average annual precipitation is around 550–600 mm.

Ambient temperature and precipitation data were obtained from a local meteorological station that recorded environmental parameters at hourly intervals. Based on these data, mean daily ambient temperatures were calculated, ranging from 8.4 °C to 32.3 °C during the study period.

Based on published literature, defining 20 °C as the upper limit of the thermoneutral zone for cattle (Kic 2022; Oliveira et al., 2025), days were categorised into two temperature classes:

- days with mean ambient temperature < 20 °C (thermoneutral conditions),
- days with mean ambient temperature ≥ 20 °C (potential heat stress conditions).

The use of a fixed 20 °C threshold was chosen to create a clear and practically interpretable dichotomous classification suitable for extensive pasture-based management. Although the Temperature-Humidity Index (THI) provides a more comprehensive measure of heat load, relative humidity was not continuously recorded directly at pasture level. Moreover, the farm was not equipped with active cooling systems such as fans or sprinklers. Animals relied solely on natural shade and free air circulation without technological cooling interventions. Therefore, the objective was not to model

a complex thermal index but to identify a practical temperature threshold relevant for pasture-based beef cattle management. It should be noted that several studies report initial behavioural alterations in beef cattle from approximately 18–20 °C onward, particularly under direct solar radiation in pasture systems lacking technological cooling.

2.4 Statistical Analysis

The primary data obtained were first processed, cleaned, and organised into a structured database using MS Excel (Microsoft Corporation, Redmond, Washington, USA). After checking the data for completeness and accuracy, further analyses were performed using IBM SPSS Statistics, version 26 (IBM Corporation, Armonk, New York, USA).

Statistical analyses were conducted to evaluate the effects of parity, ambient temperature, and precipitation on the behaviour of Aubrac cows. Differences in behavioural variables among parity groups (parity 0, 1, and 2) were assessed using one-way analysis of variance (ANOVA). LSD post-hoc tests were applied to identify statistically significant pairwise differences between groups. Effect sizes were expressed as partial eta squared (η^2).

Relationships between behavioural indicators (feeding, ruminating, standing, and resting) and meteorological variables (mean daily ambient temperature and precipitation) were analysed using the Pearson correlation coefficient. Correlation analyses were performed:

- within each parity group,
- across the entire dataset,
- and after stratification of days according to ambient temperature (< 20 °C and \geq 20 °C).

Precipitation was quantified as total daily rainfall (mm/day) based on data from the local meteorological station. In statistical analyses, precipitation was treated as a continuous variable rather than a binary variable (rain/no rain), in order to preserve information on rainfall intensity.

Multiple levels of statistical significance were applied in the analysis. Differences were considered statistically significant at $P < 0.05$, highly significant at $P < 0.01$, and very highly significant at $P < 0.001$.

3 Results and Discussion

This study aimed to determine whether ambient temperature and/or precipitation affect the behaviour of Aubrac cows on a selected farm and whether these responses differ according to parity. Studies focusing on the effects of weather on grazing cattle are essential today. With global temperatures and climate change showing a steady upward trend, it is extremely important to determine how these changes will affect animals. The insights gained from this research could guide approaches to alleviating heat stress in cows, thereby improving both animal welfare and their productivity in outdoor environments. The results show that parity influenced all behavioural variables (Table 1). The models used (ANOVA, LSD post-hoc, and effect size) showed only a small amount of variation in feeding ($P = 0.006$) and standing ($P = 0.004$), but a moderate amount of variation in ruminating ($P < 0.001$) and resting ($P < 0.001$). LSD post-hoc test showed that second-lactation cows fed more than heifers ($\Delta = 0.564$, $P = 0.002$). Ruminating was different in all groups: first lactation cows ruminated the most, heifers the least, and second lactation cows were in between (all $P \leq 0.026$). Standing also differed in all groups: second lactation cows stood the most, and first lactation cows stood the least (all $P \leq 0.032$). Resting decreased with parity ($0 > 1 > 2$; all $P < 0.001$).

This suggests that differences between parity groups are clearer in resting/lying and rumination than in feeding, because in grazing systems, feeding time is often limited by grass availability, group synchrony, and daily grazing routines. These findings are consistent with findings of Leliveld et al. (2023), who reported significant parity effects and parity \times THI interactions in sensor-derived behaviours. In their study, cows with ≥ 3 lactations generally showed more time ruminating and in low

Table 1 Differences in behaviour among parity groups (0/1/2): one-way ANOVA, LSD post-hoc, and effect size

Behaviour	ANOVA	P	η^2	LSD post-hoc (significant pairs, mean diff., P)
Feeding	$F(2, 2805) = 5.115$	0.006	0.004	2 > 0 ($\Delta = 0.564$, 0.002)
Ruminating	$F(2, 2805) = 90.214$	< 0.001	0.060	1 > 0 ($\Delta = 2.178$, $P < 0.001$); 2 > 0 ($\Delta = 1.617$, 0.001); 1 > 2 ($\Delta = 0.561$, 0.026)
Standing	$F(2, 2805) = 5.561$	0.004	0.004	0 > 1 ($\Delta = 0.548$, 0.028); 2 > 0 ($\Delta = 0.604$, 0.032); 2 > 1 ($\Delta = 1.152$, < 0.001)
Resting	$F(2, 2805) = 106.676$	< 0.001	0.071	0 > 1 ($\Delta = 1.232$, < 0.001); 0 > 2 ($\Delta = 2.034$, < 0.001); 1 > 2 ($\Delta = 0.802$, < 0.001)

η^2 – partial eta squared (interpretation: ~ 0.01 small, ~ 0.06 moderate, ~ 0.14 large; conventional benchmarks). Parity effects were small for feeding and standing ($\eta^2 \approx 0.004$) and moderate for ruminating and resting ($\eta^2 = 0.060$ – 0.071)

Table 2 Pearson correlations between precipitation and behaviour by parity group (overall)

Group	N	Feeding (<i>r, P</i>)	Ruminating (<i>r, P</i>)	Standing (<i>r, P</i>)	Resting (<i>r, P</i>)
Parity 0	1995	0.037, 0.103	0.229***, < 0.001	-0.217***, < 0.001	0.093***, < 0.001
Parity 1	420	0.046, 0.349	0.127**, 0.009	-0.170***, < 0.001	0.109*, 0.025
Parity 2	315	0.089, 0.115	0.252***, < 0.001	-0.209***, 0.001	0.134*, 0.017

Significance levels in table: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

activity and less time in high activity than cows with fewer lactations at higher THI categories, whereas primiparous cows tended to spend more time eating and in high activity under hotter conditions.

Across the full dataset within each parity group (Table 2), precipitation was not associated with feeding ($P \geq 0.103$), but it was related to other behaviours. Positive correlations were observed between precipitation and ruminating ($r = 0.127-0.252$; $P \leq 0.009$), and between precipitation and resting ($r = 0.093-0.134$; $P \leq 0.025$), while standing showed negative correlations ($r = -0.170$ to -0.217 ; $P < 0.001$). Although these correlations were small to small-moderate in size, they were consistent across all parity groups, indicating longer ruminating and resting and shorter standing during wetter conditions. These findings are in accordance with Graunke et al. (2011), who reported that during precipitation (rain/snow), cows were lying more, ruminating more, and feeding less (especially at low chill temperature). However, they also observed a decrease in feeding, while we found no feeding-precipitation association. Weather-related shifts in behaviour in cattle were also found by Redbo et al. (2001). They found that bad weather and precipitation shift the animal's behaviour towards comfort (resting/lying) and rumination. Tullo et al. (2019) found that in a moderate thermal range (THI \approx 50–57; \sim 8–13 °C), cows spent more time lying on rainy days than on clear days (11.4 h vs 9.2 h on average). This might confirm our positive observations for resting periods ($r = 0.093-0.134$).

After splitting the data by temperature (Table 3), precipitation behaviour relationships were more pronounced on warm days ($T \geq 20$ °C). In all parity

groups at $T \geq 20$ °C, precipitation correlated positively with ruminating ($P \leq 0.004$) and resting ($P \leq 0.036$), and negatively with standing ($r = -0.190$ to -0.246 ; $P < 0.001$), whereas feeding remained non-significant ($P \geq 0.140$). In contrast, at $T < 20$ °C, precipitation was generally unrelated to behaviour ($P > 0.10$), except for a moderate negative association with ruminating in the group of cows on first lactation ($r = -0.310$; $P = 0.041$; $N = 44$). According to Leliveld et al. (2023), temperature causes the most behavioural shifts. Higher temperatures can be associated with a clear behavioural pattern consistent with heat-load responses, like a decrease in feeding and ruminating time and increased standing. These findings indicate that, even in a hardy beef breed under pasture conditions, behavioural time budgets are measurably altered under warmer conditions, with ruminating and resting appearing as particularly sensitive indicators. Numerous studies concluded similar results: multiparous cattle were found to decrease their lying time as THI increased, while primiparous cows did not (Stone et al., 2017). Müschner-Siemens et al. (2020) also found that during heat stress, the rumination time decreased strongest in the case of late lactation, multiparous, and late gestation cows.

For pasture-based management and welfare monitoring, behavioural indicators such as rumination and resting (standing time) appear most informative for identifying weather-related strain. Temperature should remain the priority factor in routine risk assessment, while precipitation can be considered an additional modifier during warm periods.

Although THI is commonly used to assess heat stress in dairy systems, the present study aimed to evaluate

Table 3 Correlations between precipitation and behaviour stratified by temperature (< 20 °C vs ≥ 20 °C)

Group	N	Feeding (<i>r, P</i>)	Ruminating (<i>r, P</i>)	Standing (<i>r, P</i>)	Resting (<i>r, P</i>)
Parity 0, $T < 20$ °C	209	0.068, 0.327	0.111, 0.109	0.007, 0.916	-0.023, 0.742
Parity 0, $T \geq 20$ °C	1786	0.035, 0.140	0.240***, 0.001	-0.246***, < 0.001	0.108***, < 0.001
Parity 1, $T < 20$ °C	44	0.053, 0.734	-0.310*, 0.041	0.035, 0.823	0.179, 0.244
Parity 1, $T \geq 20$ °C	376	0.046, 0.375	0.149**, 0.004	-0.190***, < 0.001	0.108*, 0.036
Parity 2, $T < 20$ °C	33	0.151, 0.401	-0.219, 0.221	-0.046, 0.799	0.164, 0.363
Parity 2, $T \geq 20$ °C	282	0.086, 0.151	0.278***, 0.001	-0.234***, < 0.001	0.137*, 0.022

Significance levels in table: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

behavioural responses under extensive pasture conditions without technological cooling. Therefore, a simple temperature-based classification was considered more suitable for practical farm interpretation. Future research could integrate humidity, wind speed, and solar radiation into a multivariable heat load index applicable to grazing beef systems.

Studies like this need to be conducted to evaluate the contradictions between weather parameters (temperature, humidity, wind, precipitation) and their impact on grazing cows to suggest a multivector model useful for the future.

4 Conclusions

Based on the used models, we can conclude that parity is a significant source of behavioural variability in grazing Aubrac cows. It has a slight effect on feeding and standing and a moderate effect on rumination and resting. The study did not show a significant effect of precipitation on feeding, but it was consistently associated with longer rumination and lying and shorter standing – i.e., with more “stationary” behaviour in rainy and wet conditions. These relationships were largely temperature-dependent. At temperatures above 20 °C, they were repeatedly confirmed across parity (small to small-medium effects), while at temperatures under 20 °C, they were mostly absent. In regular and effective risk assessment, temperature should be the priority, while precipitation should be taken into account as an additional factor, especially in summer and warm periods.

Limitations of the Study

This study was conducted under specific environmental and management conditions, which may limit the generalisability of the results to other regions, production systems, or cattle breeds. Only selected climatic variables (temperature and precipitation) were included in the models, and other potentially relevant environmental or management factors were not analysed. In addition, the observational design does not allow for definitive causal conclusions.

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and rumination sensors for detecting estrus and early diagnosis of the mammary gland and hoof diseases in dairy cows.

Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

Conceptualization, M.M and I.S; methodology, M.M. and P.J; statistical analysis, P.J; writing – original draft preparation, I.S., J.D., and M.M.; writing – review and editing, M.M., I.S., and J.D. All authors have read and agreed to the published version of the manuscript.

AI and AI-Assisted Technologies use Declaration

The following AI tools-AI-assisted technologies were used during the preparation of the manuscript: Chat GPT 5.2 for English corrections and text revision for better readability. The authors take full responsibility for the content of the article.

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