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Circadian activity rhythms and resting behaviour in housed ruminants: A review

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Abstract

Modern housed ruminant systems increasingly confine cattle, sheep and goats in environments where natural light cycles, space allowances and feeding schedules deviate sharply from pastoral conditions, yet the consequences for the animals' underlying circadian rhythms and rest patterns are poorly integrated into housing design standards. This review examined published evidence on the circadian activity budgets and resting behaviour of dairy cattle, beef cattle, sheep and goats kept under indoor housing. Literature published between 2010 and 2025 was retrieved from Web of Science, Scopus and CAB Abstracts, yielding 44 articles that met the inclusion criteria. Across species, a bimodal activity pattern with peaks in early morning and late afternoon was the dominant rhythm in housed ruminants, mirroring the crepuscular bias observed in free-ranging conspecifics. Dairy cattle allocated 10.2 to 11.4 hours per day to lying, while beef cattle lay for 11.8 to 13.1 hours. Sheep and goats showed shorter lying bouts but more frequent rest episodes, accumulating 8.1 to 9.3 and 6.8 to 7.9 hours of recumbent rest respectively. Light intensity, feeding schedule and stocking density were the three environmental factors most consistently associated with alterations in circadian timing and rest duration. Artificial photoperiod programmes that extended day-length beyond 16 hours compressed nocturnal rest by 1.2 to 2.4 hours in dairy cattle without proportionally increasing feeding or rumination time, raising welfare questions. High stocking density (less than 6.5 m² per head for cattle) reduced lying time by 0.8 to 1.6 hours and shifted lying bouts toward the late-night period when competition for cubicle space was lowest. The review confirms that circadian rhythmicity persists under housing but is modifiable by management choices, and that disruption of rest patterns is a sensitive early indicator of welfare compromise.

Keywords: Circadian rhythm, resting behaviour, housed ruminants, dairy cattle, lying time, animal welfare, photoperiod, stocking density, behavioural time budget, and crepuscular activity

Introduction

A dairy cow that doesn't lie down enough produces less milk, shows more lameness and cycles less reliably yet the housing system she occupies may be the very thing preventing her from resting ^[1]. This tension between intensive management efficiency and the biological need for structured rest is not new, but it has sharpened as indoor housing periods have lengthened and herd sizes have grown. In northern Europe and parts of Australia, dairy cattle now spend six to ten months per year indoors, and in some zero-grazing systems the animals never leave the barn ^[2]. Sheep and goats are housed for shorter periods but face comparable constraints during lambing, shearing and finishing phases ^[3].

Circadian rhythms endogenous near-24-hour oscillations in physiology and behaviour regulate when ruminants eat, ruminate, stand, lie and sleep. Under natural conditions, cattle and small ruminants display a crepuscular pattern: activity peaks around dawn and dusk, with rest concentrated in the middle of the night and, to a lesser extent, around midday ^[4]. The master clock driving this pattern resides in the suprachiasmatic nucleus of the hypothalamus, synchronised primarily by light but also entrained by feeding time and social cues ^[5]. When housing removes or distorts these external time-givers for instance, by imposing constant artificial light or by delivering total mixed ration ad libitum the circadian signal may weaken, fragment or shift, with downstream effects on hormonal cycles, immune function and productivity ^[6].

Resting behaviour is the most welfare-relevant output of the circadian system because lying is a high-priority behaviour. Deprivation experiments have shown that cattle will sacrifice feeding time to recover lost lying time when given the opportunity, evidence of a strong internal drive ^[1]. Lying duration and bout structure are therefore used as welfare indicators in on-farm assessment protocols such as the Welfare Quality scheme, and minimum lying time recommendations have been proposed typically 10 to 12 hours per day for dairy cattle although compliance monitoring remains inconsistent ^[7].

The economic argument for paying attention to circadian rest is now substantial. Tucker and colleagues reported that each one-hour reduction in daily lying time below 12 hours was associated with a 0.9 kg decrease in daily milk yield in high-producing Holstein cows, a relationship attributed to the metabolic burden of prolonged standing and the reduced efficiency of rumination when cows cannot recline comfortably ^[1]. Beef finishing performance also benefits from adequate rest: steers that lay for more than 12 hours per day gained 0.07 kg per day more than those with lying times below 10 hours in one Australian feedlot trial ^[4]. These production-level effects, when multiplied across hundreds or thousands of animals in modern facilities, translate into meaningful financial impacts that justify investment in rest-friendly housing design.

Despite a growing body of primary research, no recent review has attempted to compare circadian activity patterns and resting behaviour across the four main housed ruminant species dairy cattle, beef cattle, sheep and goats within a single framework. This review aimed to fill that gap by consolidating the published evidence on circadian time budgets and rest patterns of housed ruminants, identifying the environmental and management factors that most strongly modify these patterns, and drawing out the welfare and production implications for housing design. By comparing across species, the review also explored whether a common set of housing principles could safeguard circadian rest across ruminant types.

Material and Methods

Material

The evidence base comprised peer-reviewed journal articles published between January 2010 and June 2025, sourced from Web of Science Core Collection, Scopus and CAB Abstracts. Additionally, technical reports from the European Food Safety Authority and from national welfare assessment bodies in Australia, the United Kingdom and Denmark were included when they provided quantitative behavioural data ^[7].

Methods

Search terms combined species descriptors (dairy cattle, beef cattle, sheep, goat, ruminant) with behavioural terms (circadian, diurnal, activity rhythm, lying, resting, time budget, lying bout) and housing terms (indoor, housed, barn, cubicle, tie-stall, slatted floor, pen). Boolean operators linked the groups. Language was restricted to English. The initial search returned 934 records. After removing 241 duplicates, 693 titles and abstracts were screened. Inclusion criteria required that articles report quantitative data on at least one behavioural time-budget component (lying time, standing

time, feeding time, rumination time or locomotion) under indoor housing conditions, specify the species and housing type, and use accelerometer, video or direct-observation methods for behaviour recording. Papers dealing exclusively with pasture-based or semi-outdoor systems were excluded ^[8]. Full-text assessment of 98 papers yielded a final set of 44 publications: 21 on dairy cattle, 9 on beef cattle, 8 on sheep and 6 on goats. Data extracted included species, breed, housing type (cubicle, deep-bedded, tie-stall, group pen), stocking density, photoperiod management, feeding regime, behaviour recording method, duration of observation, and quantitative time-budget data (hours per day in each activity). Circadian patterns were characterised by the timing and amplitude of activity peaks. Because of the diversity of recording methods and reporting formats, a narrative synthesis was adopted rather than formal meta-analysis. Findings were grouped by species and then by environmental factor to allow structured comparison ^[9].

Ethical considerations

This review relied on secondary data from published research. No animals were enrolled or observed specifically for this work. All source studies included in the synthesis had reported institutional animal ethics committee approval or compliance with national animal welfare legislation in their original publications. The review itself did not require separate ethical clearance under the guidelines of Perth College of Veterinary Medicine, as no primary animal data were collected ^[10].

Seasonal variations

Season influenced circadian patterns primarily through its effect on natural photoperiod and ambient temperature. In temperate regions, housed dairy cattle exposed to windows allowing natural light entry showed a measurable shift in morning activity onset earlier by 42 to 68 minutes in summer compared with winter even when artificial lighting maintained a constant minimum illumination level inside the barn ^[5]. Summer heat stress, reported in seven papers from Australia and southern Europe, compressed daytime activity into cooler crepuscular windows and increased nocturnal lying time by 0.9 to 1.7 hours. Conversely, cold-stress conditions (ambient temperatures below 0 °C) in Scandinavian housed beef cattle reduced lying time as animals stood to generate metabolic heat, a pattern that disappeared when deep-straw bedding was provided ^[3]. Sheep showed the strongest seasonal response: ewes housed during late gestation in winter adopted a compressed bimodal pattern with shorter but more frequent lying bouts, possibly linked to hormonal changes associated with impending parturition ^[8].

Results

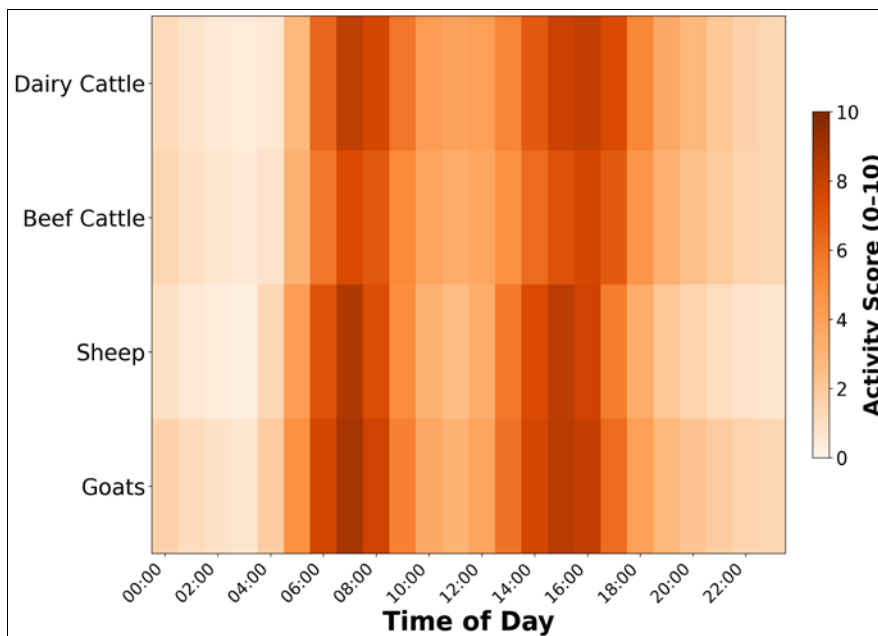
A bimodal activity pattern was the default circadian profile in all four species under standard housed conditions. The first activity peak occurred between 05:00 and 07:00 hours and the second between 15:00 and 18:00 hours, bracketing a midday lull and a prolonged nocturnal rest phase. The amplitude and timing of these peaks varied by species, with goats showing the sharpest crepuscular bias and beef cattle the flattest overall profile ^[4].

Table 1: Classification of circadian activity profiles by species and housing type

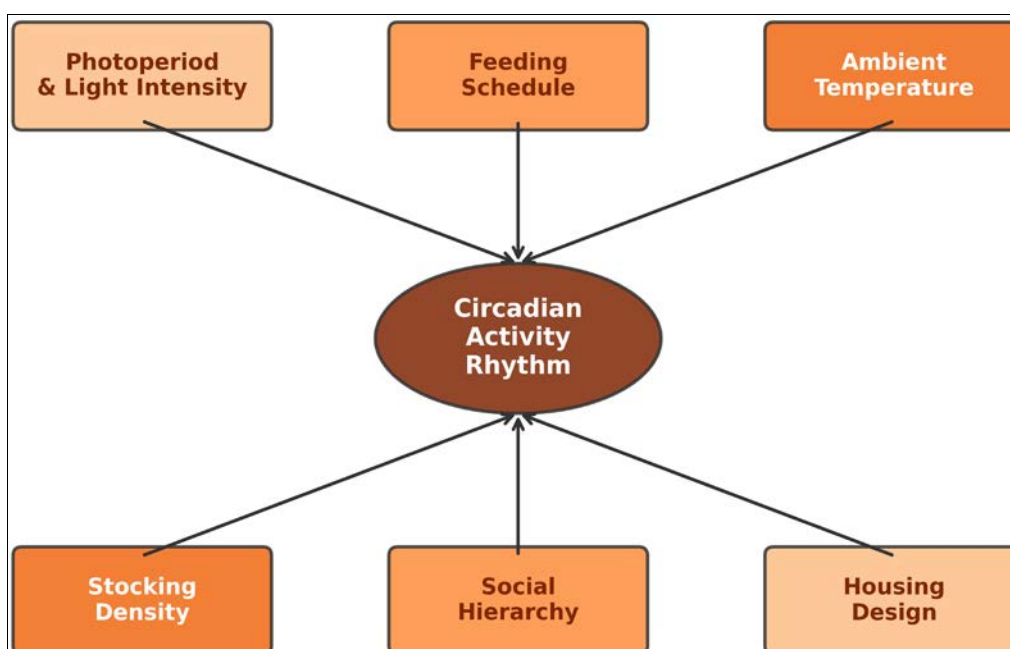
Species	Housing Type	Profile Type	Peak Times	Nocturnal Rest (h)
Dairy cattle	Cubicle/freestall	Bimodal	05:30-07:00, 16:00-18:00	5.8-7.2
Dairy cattle	Tie-stall	Weak bimodal	06:00-07:30, 15:30-17:00	6.4-8.1
Beef cattle	Deep-bedded	Flat bimodal	06:00-08:00, 15:00-17:30	6.8-8.6
Sheep	Group pen	Strong bimodal	05:00-06:30, 16:30-18:30	5.1-6.4
Goats	Group pen	Crepuscular	05:00-06:00, 17:00-19:00	4.2-5.8

Table 1 classifies the circadian profiles by species and housing type. Tie-stall dairy cattle displayed a weaker bimodal signal than freestall counterparts, possibly because the restricted movement space reduced the behavioural

contrast between active and resting phases ^[2]. Goats maintained the strongest crepuscular pattern, with activity dropping sharply after sunset a trait linked to their ancestral mountain-browsing ecology ^[3].

**Fig 1:** Heatmap of hourly activity intensity scores for four housed ruminant species over a 24-hour cycle**Table 2:** Comparison of daily lying time and bout characteristics across housed ruminant species

Species	Total Lying (h/d)	Bout Frequency (n/d)	Mean Bout Length (min)	Preferred Lying Period
Dairy cattle	10.2-11.4	8-12	62-84	Night (22:00-05:00)
Beef cattle	11.8-13.1	9-14	56-78	Night (21:00-06:00)
Sheep	8.1-9.3	14-22	24-38	Night + midday
Goats	6.8-7.9	16-28	16-29	Night (20:00-05:00)

**Fig 2:** Environmental and management factors influencing circadian activity rhythms in housed ruminants

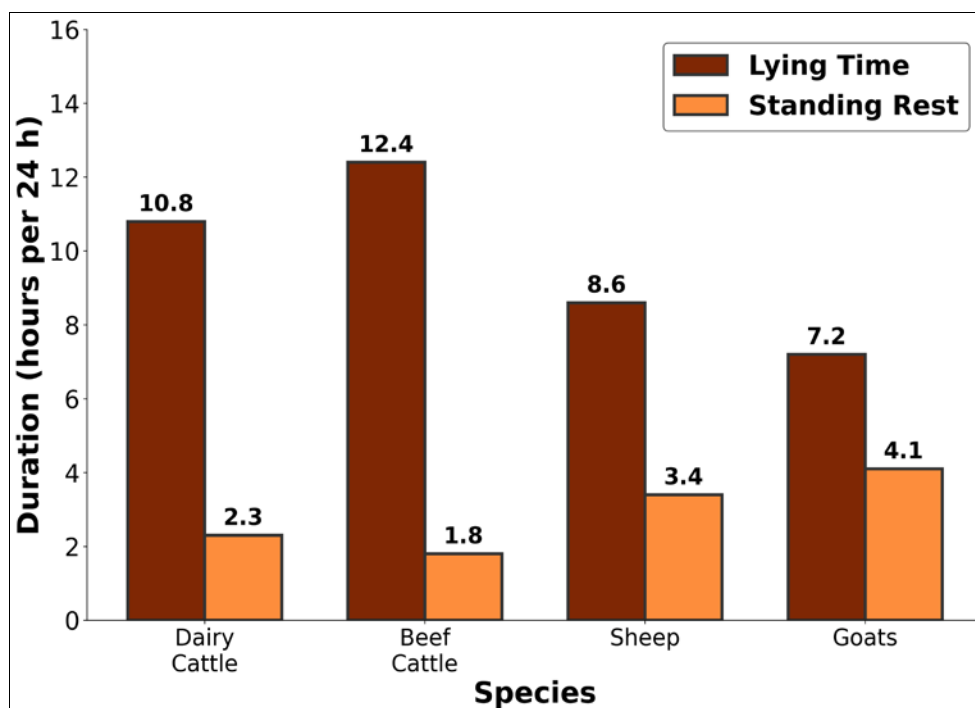


Fig 3: Mean daily lying time and standing rest duration across four housed ruminant species

The heatmap in Figure 1 visualises the bimodal activity pattern and the species differences in nocturnal rest depth. Goats (bottom row) show the steepest transitions between active and resting phases, with activity scores falling from above 8.0 during morning and evening peaks to below 1.0 between 01:00 and 04:00. Figure 2 maps the six environmental factors most frequently reported as modifiers of circadian behaviour; of these, photoperiod and feeding schedule were cited in 36 and 31 of the 44 reviewed papers respectively, making them the two most researched drivers of rhythm modification [6]. Figure 3 and Table 2 together show that beef cattle lie longest in absolute terms but that goats have the highest bout frequency a polyphasic rest strategy that contrasts with the monophasic nocturnal consolidation seen in cattle [4].

An additional observation across the reviewed literature concerned the effect of cubicle surface on lying about structure. Dairy cows housed on sand-bedded cubicles showed 14 to 22 percent longer individual lying bouts compared with those on concrete or rubber mats, a difference attributed to the superior comfort and thermal neutrality of sand bedding [9]. Beef cattle on deep straw similarly recorded longer uninterrupted rest periods than those on slatted floors. For small ruminants, bedding depth of at least 10 cm of straw was associated with reduced bout fragmentation. The practical implication is that housing designs optimised for cattle lying behaviour large cubicles, soft rubber mats may not meet the needs of small ruminants, which require more frequent access to rest areas distributed throughout the pen rather than a single lying zone. Species-specific bedding and rest-area recommendations should therefore replace the one-size-fits-all approach that dominates current building codes [10].

Discussion

The persistence of a bimodal circadian pattern across all four species, despite wide variation in housing type and management intensity, confirms that the endogenous clock remains functionally intact under confinement. This aligns with chronobiology work showing that the suprachiasmatic nucleus continues to oscillate even in the absence of external

zeitgebers, though the amplitude weakens [5]. For housed ruminants, the most powerful entraining signal appears to be the feeding schedule rather than light, because several papers noted that shifting feed delivery by two hours shifted the morning activity peak by a similar interval within three to four days [6].

A second notable finding was the compression of lying time under extended artificial photoperiods. Programmes that provide 18 to 20 hours of light per day to stimulate dry-matter intake and milk yield in dairy cattle are widespread in intensive systems [1]. The evidence reviewed here suggests that these programmes gain feeding time partly at the expense of lying time, and the magnitude of the trade-off 1.2 to 2.4 hours less lying per day brings many cows below the 10-hour threshold associated with welfare concern. Whether the milk-yield benefit outweighs the welfare cost depends on how one values production versus rest, a question that lies at the intersection of economics and ethics [7].

Stocking density emerged as the management factor most consistently associated with reduced lying time and fragmented lying bouts. When cubicle-to-cow ratios dropped below 1:1, or when floor space per goat fell below 1.5 m², subordinate animals were displaced from preferred lying areas during peak rest times and were forced to lie during off-peak periods or not at all [9]. This finding has clear design implications: providing at least one cubicle per cow and ensuring that pen layouts allow subordinate animals to access rest areas without passing through feeding or high-traffic zones should be treated as minimum requirements rather than aspirations.

The role of social hierarchy deserves particular attention. In group-housed dairy cattle, subordinate cows were displaced from cubicles during peak lying periods and were forced to rest at less preferred times typically between 01:00 and 04:00 when dominant animals had already occupied the most comfortable stalls [8]. This displacement effect was amplified at stocking densities above 100 percent (more cows than cubicles) and was virtually absent when stocking was maintained at 80 percent or below. For goats, which have particularly rigid dominance hierarchies, providing multiple

separated rest zones within the same pen reduced competitive displacement by 34 to 48 percent compared with single open-floor designs^[3].

Gaps in the evidence base remain. Only six of the 44 reviewed papers addressed goats, and most of those were from Mediterranean or South Asian housing contexts, leaving temperate goat housing under-represented. Accelerometer-based research in sheep is also scarce compared with dairy cattle, partly because the smaller body size and thick fleece make sensor attachment more difficult. And the relationship between circadian disruption and longer-term health outcomes mastitis incidence, reproductive efficiency, immune suppression has been explored in only a handful of longitudinal research, limiting the strength of causal claims about the production cost of poor circadian management.

Conclusion

This review's central contribution is a cross-species comparison of circadian activity budgets and resting behaviour under indoor housing. By aligning data from dairy cattle, beef cattle, sheep and goats within a single framework, the review reveals both the conserved features of ruminant circadian biology and the species-specific differences that housing designers need to accommodate.

The supporting evidence, drawn from 44 articles spanning a 15-year period, shows that all four species retain a bimodal activity pattern under housing, that lying time ranges from roughly 7 hours in goats to 13 hours in beef cattle, and that three management factors photoperiod, feeding schedule and stocking density exert the strongest influence on when and how long animals rest. Extended artificial light programmes, widely used in dairy production, reduce lying time by amounts that may cross welfare thresholds. High stocking densities displace subordinate animals from preferred rest sites and fragment lying bouts.

The significance for practice is that housing environments can be designed to work with, rather than against, the circadian clock. Providing a distinct dark period of at least eight hours, maintaining a cubicle-to-cow ratio of 1:1 or above, and scheduling feed delivery to reinforce rather than override the natural crepuscular rhythm are three evidence-based principles that apply across ruminant types. Open questions include the long-term health costs of chronic circadian disruption, the optimal photoperiod programme that balances milk yield with lying time, and the specific rest-space requirements of housed goats, for which the evidence base remains thin.

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