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Effect of Feeding Level and Breed on the Daily Activity Budget of Lactating Beef Cows Fed Total Mixed Ration

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Abstract: The objective of this experiment was to evaluate the effect of two feeding levels and two breeds on the daily activity budget of indoor-housed lactating beef cows fed total mixed ration (TMR). We used a total of 20 cows from Parda de Montaña (PA, n = 14) and Pirenaica (PI, n = 6) breeds. To evaluate the feeding level, PA cows were fed the TMR at the maintenance level and in a restricted amount. To evaluate the breed effect, PA and PI cows were fed at maintenance. All cows were video recorded for 24 consecutive hours at weeks 3, 8 and 13 of lactation. Scan sampling at 10-min intervals was used to obtain information on their daily activity budget. The restricted feeding level did not affect the time standing or lying, but it reduced the time eating the TMR and increased the time exploring and/or eating straw bedding. Both breeds showed a similar daily activity budget, except for the time that they spent foraging straw, which was lower in PA than in PI breed. In conclusion, feeding level and breed of lactating beef cows fed on TMR during the indoor housing period did not affect the main contributors to the daily activity budget.

Keywords: cattle; behaviour; indoor; restricted feeding; suckler cows

1. Introduction

The first step toward better animal welfare is to understand the animals' needs [1]. Some of these needs are relatively simple, such as nutrition. Beef cows may be allotted indoors during periods of pasture scarcity. In the indoor periods, cows are normally supplied with preserved forages (hays or silages) sometimes supplemented with concentrates during lactation. Dry total mixed rations (TMR) allow a balanced supply of forage to concentrate ratio in normal practices. However, farmers often determine restricted feeding levels, below ad libitum intake by the cows, to reduce costs considerably. Thereby, the feeding level during the housing period may not meet the nutritional requirements of the cows, altering their intake behaviour (time eating and drinking, and intake rate), as well as rumination activity [2]. Behavioural differences between breeds also exist [3]. Behaviour is one of the most commonly used and sensitive indicators of animal welfare [4]. It has been seen that changes in cows' behaviour are valid indicators of their health and welfare problems. Available information about cows' behaviour has the potential to improve several areas of farm management. The daily activity budget is a useful tool that offers considerable help with making precise decisions on practical strategies to enhanced cattle welfare and health status [5].

In Spain, a wide range of cattle breeds are raised. The variation between these breeds in their activity budget under the same feeding management is unknown. Parda de Montaña (PA) and Pirenaica (PI) are two similar frame-sized suckled breeds [6], widely spread throughout Northern Spain (approximately 28 and 33 thousand reproductive stock heads, respectively) [7]. The former is grey-coated and comes from the selection for beef and mothering abilities from the old Brown Swiss, which was introduced in the country two centuries ago as a dual-purpose breed (milk-beef). The latter is a local blond-coated hardy breed from the mountain area of Pyrenees, which was utilized in the past as a triple-purpose breed (work-milk-beef) and is currently used for beef production. This study aimed to evaluate the effect of feeding level in housed PA beef cows (restricted feeding strategy meeting 75% of their nutritional requirements, 0.75 × M, vs. maintenance feeding level, 1 × M) and breed (PA vs. PI cows, both fed at 1 × M) on their daily activity budgets supplying a TMR diet during lactation.

2. Materials and Methods

The animals were handled in accordance with the Spanish Animal Protection Regulation RD 53/2013, which complies with the European Union Directive 2010/63 with regard to the protection of animals used for experimental and other scientific purposes. The cows were raised in commercial conditions following the Council Directive 98/58/EC concerning the protection of animals kept for farming purposes.

2.1. Animals, Diets and Experimental Design

A total of 20 multiparous lactating beef cows (8 ± 3 years of age, means ± standard deviation), 14 PA (post-calving body-weight 559 ± 52 kg) and 6 PI cows (post-calving body-weight 578 ± 75 kg) were selected from the autumn-winter calving periods from 'La Garcipollera' Research Station (North-eastern Spain). Although this study included 5- to 11-year-old beef cows, they are considered rather similar in terms of productive performance [8]. No signs of disease were observed prior to the experiment. The cows were allotted in three contiguous loose-housing pens (12–14 cows/pen, with a space allowance 10 m^2/cow) with a feed bunk. The TMR was distributed once a day (at 09:30 a.m.) (Table 1). No more management activities that may have challenged the cow's time budget were carried out. The amount of feed supplied was 10.5 kg to each restricted-fed PA cow (0.75 × M-PA), 13 kg to each PA cow fed at maintenance (1 × M-PA), and 12 kg to each PI cow fed at maintenance (1 × M-PI) on an as-fed basis. The ingredients of the TMR had been chopped using a 2-cm screen. The TMR was sampled monthly and analysed according to AOAC [9]. Vitamin-mineral block supplements were available to avoid micronutrient deficiency.

Table 1. Chemical composition of the total mixed ration (TMR) used in the experiment.

Nutrient	g/kg of Dry Matter (DM), unless Otherwise Stated
DM (g/kg)	903
Ether extract	12
Ash	77
Crude Protein	94
Neutral-detergent Fiber	538
Acid-detergent Fiber	297

Feedstuffs (g/kg fresh-weight basis): barley straw (470), barley grains (126), dehydrated alfalfa (100), sugar-beet molasses (80), citric pulp pellets (72), maize gluten meal (54), soybean meal (38), rapeseed meal (38), alfalfa pellets (12) and vitamin and mineral supplement (10). Vitamin and mineral supplement contained per kg (fresh-weight basis): Ca 107 g, P 85 g, Cl 156 g, Mg 9 g, Na 102 g, S 20 g, Fe 4 g, Zn 12 g, vitamin A 12,000 UI/kg, vitamin D3 1200 UI/kg, vitamin E (α-tocopherols 91%) 53 mg/kg, Cu 20 mg/kg.

The diet met the maintenance requirements for energy and protein in a 560-kg or 585-kg beef cow producing approximately 9 kg or 8 kg of energy-corrected milk in PA and PI, respectively [10].

The cows were allowed to nurse their calves ad libitum. Nursing behaviour and social behaviour outcomes were reported elsewhere [11,12].

2.2. Activity Recordings

Activity budget recordings were obtained for 24 consecutive hours in 6 sub-groups composed of 3-4 cow-calf pairs (a total of 20 pairs) balanced for calf sex at weeks 3, 8 and 13 of lactation. There was only a recording pen (4.5 m × 7.5 m, which was a sub-part of the main pen), located close to the cows' resting area. The recording pen and the others were equally designed. Its floor was spread with abundant barley straw (8–10 kg/m^2) bedding from one day before behavioural observations to allow the cows to lie down comfortably. The diet was supplied to the group in a collective feeder bunk (68 cm-wide, 1.3 to 1 m of trough space per cow, depending on whether batch size was 3 or 4). The water was supplied in an individual cup bowl drinker with a reservoir (20-cm diameter, 1 drinker per 3–4 cows). Each sub-group of 3–4 cow-calf pairs was brought into the recording pen 24 h prior to sampling to acclimate them for the following 24 h recording of activity budget (space allowance range from 8.4 to 11.3 m^2/cow-calf pair, varying if batch size was 3 or 4, but constant across observing days). The position of the camera (Sony Hi8 Handycam, Sony, Japan) was located outside of the animal area on an elevated observation position that allowed an overview of the pen (non-invasive record). The cows were brought into the recording pen according to their calving date, followed immediately by their calves. The same recording pen was used with the different cow-calf pairs because cows were not oestrus synchronized (the calving period lasted two months) and recordings were conducted at specific weeks of lactation. The composition of sub-groups remained constant (same cow-calf pairs) across observing days. Every cow-calf pair had coloured neck collars to aid identification. Cows in heat were not included in recordings.

The observations were performed through video recording using the instantaneous scan sampling technique [13] at 10-min sampling intervals. A single observer viewed all the activity budget video recordings. The observer was trained by a focus group and tested against established reference material. To calculate the duration of each activity, this method involves extrapolation for the 10 min separating two successive scans, and it correlates highly with continuous sampling in feedlot cattle conditions [14]. If two different behaviours were recorded during two consecutive scans, it was considered that the cow spent 10 min in each activity. The recorded activities are shown in Table 2.

Table 2. Recorded behaviours in the cows.

Behaviour Class	Description
Standing	Inactive upright posture, including idling, eating the TMR, exploring and/or eating straw bedding, drinking water, and nursing and grooming their calves and socializing with other dams and calves in standing position
Standing idling	Inactive upright posture without locomotion or any other concurrent activity
Exploring and/or eating straw bedding	Head interaction with straw bedding
Eating the total mixed ration (TMR)	Head over the feeding rack or in the bunk
Drinking water	Head over or in the water bowl
Lying down	Body contact with the ground, including idling and socializing with their calves and other dams or calves
Lying idling	Body contact with the ground without any other concurrent activity

In addition, the intake rate was calculated as the quotient between the corresponding TMR ration supply and the time eating. The time eating was recorded individually while daily feed consumption was estimated by weighing the feed allocated to the group and dividing it by the number of animals,

as reported elsewhere [15]. The assessment of feed refusals was evaluated during the experiment. The recording pen was artificially illuminated at night (200 lx at 5-m height level) to allow monitoring of the 24 h-cycle.

2.3. Statistical Analysis

The data were analysed with the SAS statistical package (version 9.1, SAS Institute Inc. Cary, NC, USA) through the following mixed models with repeated measurements:

$$y_{ijkl} = \mu + \alpha_i + d_j + \beta_k + \varepsilon_{ijkl} \quad (1)$$

where:

y_{ijk} = dependent variable (daily activity budget variables),
μ = overall mean,
α_i = fixed effect of the feeding level (0.75 × M vs. 1 × M) or breed (PA vs. PI) i,
d_j = random effect of the cow j,
β_k = fixed effect of the week of lactation (3, 8 or 13) k and,
ε_{ijk} = residual error.

Least square means and their standard error are described. The separation of means was carried out with Tukey's test. The level of significance was set at 0.05.

3. Results

3.1. Effect of Feeding Level

The daily activity budget of lactating beef cows as affected by feeding level and breed is shown in Table 3. In PA breed, the restricted feeding level did not affect the time standing or lying, which were similar in both treatments ($p > 0.10$). As expected, the time eating the TMR was lower in restricted-fed (0.75 × M) than in maintenance-fed (1 × M) cows ($p < 0.001$), whereas the time exploring and/or consuming barley straw bedding was greater in 0.75 x M than in 1 × M ($p < 0.05$). In addition, the feed intake rate was numerically greater in 0.75 × M than in 1 × M, although this difference did not reach statistical significance ($p > 0.10$) due to high variability in restricted-fed cows (high standard error of the mean). There were no feed refusals throughout the experiment. The restricted feeding level did not alter the time drinking water ($p > 0.10$).

3.2. Effect of Breed

Both beef breeds showed similar daily activity budget under maintenance feeding level, except for a greater time standing idling in PA than in PI cows (Table 3, $p < 0.05$). This was offset by a numerically lower explorative and eating behaviour of straw bedding in PA compared to PI cows, although this difference did not reach statistical significance ($p > 0.10$).

Despite the fact that PA cows were supplied with 1 additional kg of TMR/day than the PI breed to support an equivalent nutrient requirement level, neither their time eating or drinking, nor their TMR intake rate, differed significantly across breeds ($p > 0.10$).

3.3. Effect of Week of Lactation

The week of lactation did not affect the daily activity budget, except for the time exploring or eating straw bedding, which was greater at week 3 than in the subsequent sampling weeks (Figure 1, $p < 0.05$).

Table 3. Daily activity budget and intake rate in indoor-housed lactating beef cows fed on TMR.

	PA (0.75 × M)	PA (1 × M)	PI (1 × M)	Contrast *p*-Values [1]	
				Feeding Level	Breed
Number of cows	7	7	6	-	-
Total time standing (h/day) [2]	14.7 ± 0.6	14.6 ± 0.6	13.9 ± 0.5	NS	NS
Time standing idling (h/day)	7.6 ± 0.5	7.7 ± 0.5	6.1 ± 0.4	NS	*
Time exploring and/or eating straw bedding (h/day)	3.7 ± 0.4	2.9 ± 0.7	3.7 ± 0.6	*	NS
Time eating the TMR (h/day)	1.5 ± 0.2	2.6 ± 0.3	2.3 ± 0.2	***	NS
Time drinking water (h/day)	0.3 ± 0.1	0.2 ± 0.3	0.5 ± 0.2	NS	NS
Total time lying down (h/day) [3]	9.3 ± 0.6	9.5 ± 0.6	10.2 ± 0.5	NS	NS
Time lying idling (h/day)	9.3 ± 0.6	9.4 ± 0.6	10.1 ± 0.5	NS	NS
TMR intake rate (g DM/min)	134 ± 27	80 ± 9	87 ± 7	NS	NS

[1] Contrasts: Feeding level (PA 0.75 × M vs. PA 1 × M), breed (PA 1 × M vs. PI 1 × M). NS = $p > 0.10$. * $p < 0.05$. *** $p < 0.001$. [2] Total time standing included the following activities: standing idling, eating, exploring and/or eating straw bedding, drinking water, and nursing and grooming their calves and socializing with other dams and calves in standing position. The time nursing and socializing activities represented 1.6, 1.2 and 1.3 h/day in PA 0.75 × M, PA 1 × M and PI 1 × M, respectively, but these were reported elsewhere [11,12]. [3] Total time lying down included the time idling and socializing with their calves and other dams or calves in lying position.

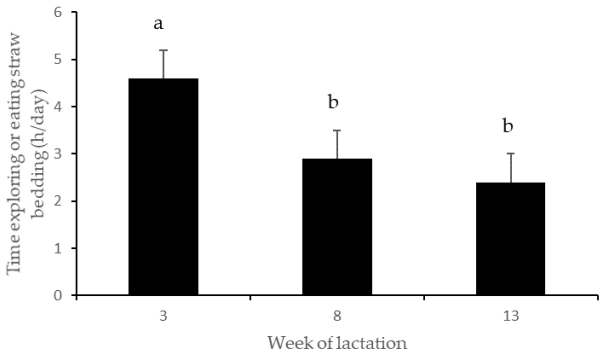

Figure 1. The effect of week of lactation on the time exploring or eating barley straw bedding by beef cows irrespective of breed (different letter between weeks denotes statistical differences, $p < 0.05$).

4. Discussion

Few studies have been undertaken to document daily budget in suckler cows during the housing period. This experiment was designed to evaluate whether the feeding level and the breed may affect the daily activity budgets of beef cows provided with a dried TMR-based diet during lactation.

Lying idling accounted for the largest share of the daily activity, which was in all groups greater than time standing idling, the second longest activity. The third major activity was dedicated to feeding the assigned diet. In this study, the time eating the TMR was lower than the observed in dairy cows (30–38 kg of milk yield) in other studies ranging from 3.5 to 7.7 h/day [16–18]. However, the dietary supply on dairy cows was also much higher (approximately twice) than in this study. In dairy cows, an increase in the number of feed distributions allows greater time eating, but represents a decrease of time lying [19]. In the current study, the ration was delivered only once a day to avoid human disturbance close to the recording pen. However, feeding time of cows fed at maintenance (1 × M) in this study was very similar to records in beef cows fed ad libitum a mixture of barley straw and barley silage (2.4 h/day for 11.6 kg DM/day) by Basarab et al. [20], which means that feeding behaviour was not limited by the experimental procedures. In fact, the intake rate of the TMR in this study was in agreement with the intake rate of Italian Podolian free-range beef cows (84 g DM/min) [21].

The time eating the TMR here was also much lower than the time grazing by these same breeds when stocked continuously on high-quality permanent pastures in spring (9.5 h/day in both breeds) [22]. Feeding time was also shorter than the observed values on pastures for other beef cows such as lactating beef cows in Norway (8.2 h/day) [23], in lactating 'Asturiana de los Valles' beef breed in

North-Western Spain (10.3 h/day) [24], or in dry beef cows on low-quality Spanish mountain ranges in summer (8.2 h/day) [25].

Likewise, the time drinking in this study was very similar to that of high-producing dairy cows (0.3 h/day in cows yielding 28–30 litres of milk/day) [16], which suggests that drinking rate in beef cows is closely tied to whether the animals are lactating and it may be adapted to drinking habits within their daily activity budget.

Concerning the effect of feeding level on time budget, outcomes in PA cows during the indoor housing period revealed that a restricted feeding level modified their main activities only mildly when compared to cows fed at maintenance, as no differences were noted in time lying idling, which reflect resting [26], and the time standing idling. However, restricted-fed cows spent significantly less time eating TMR but longer time exploring/eating straw.

The observed intake rate of the TMR in restricted-fed PA cows were closer to measures in dairy cows fed TMR (140 g DM/min) [27], which normally show a higher body condition loss. Although this intake rate was only numerically higher than that of cows fed at maintenance, our results agree with Ferris et al. [28] who reported behavioural feeding modifications to maintain feed intake in cows under feed restriction. On the other hand, the eating rate is positively related with a higher feed conversion efficiency, as efficient animals expend less energy at feeding [29]. In this experiment, although cows had similar body condition at calving, the restricted-fed PA cows lost more body-weight throughout the first 13 weeks of lactation than maintenance-fed cows ad libitum nursing (−5.5% vs. −3.9% out of calving body-weight) [11,12].

In the indoor-housing conditions of this study, breed only influenced the time standing idling. This difference may be attributed to less licking towards alien calves/cows and less agonistic events in PA than in PI cows [12], but not to different nursing activities, as they were very similar among breeds (approximately 1 h/day). Although these two local breeds were of similar frame size, PA cows spent more time standing idling than PI cows, where the latter redirected their activity towards exploration and intake of straw bedding material. This straw-based foraging time was longer than time eating the TMR.

No differences were observed between both breeds in the time spent lying down. In outdoor conditions, native Baladi dry cows showed less resting activity when compared to crossbred beef cows throughout the year (8.8 vs. 9.2 h/day for time lying idling, and 6.3 vs. 7.1 h/day for time standing idling, respectively) [30]. In the case of dairy cows, the time lying down ranges from 10 to 12 h [16,17,31]. Cows may prioritise lying, although conflict may arise in high-yielding cows between lying and eating since reduced lying can also reduce food intake and yield [32].

The time dedicated to eating the TMR did not differ between both breeds. When comparing different breeds on the Mediterranean pastures, small-frame native Baladi cows grazed for more time daily than large-frame crossed beef cows (8.1 vs. 7.0 h/day) [30], but in our case both breeds have similar frame size and mature weight. However, voluntary intake of pelleted dehydrated lucerne during lactation was higher in PA than in PI breed (20.8 vs. 18.6 kg/day in PA and PI, respectively) [33] most likely attributed to their difference in milk yield (8.7 vs. 7.1 kg/day, respectively). Hence, it seems that the maximum voluntary feed intake in these breeds much higher than the intake in the present study. Although cows were not fed ad libitum but at maintenance level (1 × M), the fact that both breeds had a similar eating rate suggests that they were able to meet their dietary requirements without altering their feeding behaviour.

In cows fed a limited amount of TMR, the time eating the straw bedding was specifically longer in week 3 of lactation. Larger negative energy balance and possibly metabolic stress could be expected in (dairy) cows that share the genetic potential for milk production. However, the present feeding strategy did not reveal any sign of severe negative energy balance in beef cows at this stage of the lactation (plasma NEFA and β-hydroxybutyrate below 0.4 mmol/l during the first month of lactation). Differences on weeks of lactation were just mild since energy-corrected milk yield at week 3 was slightly greater than at subsequent weeks (8.6 vs. 7.6 and 7.2 kg/day at weeks 3, 8 and 13 of lactation, respectively) [34].

Large herbivores like cattle spend a substantial amount of time foraging and feeding. Thereby, our results are in line with Redbo [35], who showed that cattle would require a minimum duration of time spent feeding in order to receive sufficient negative feedback on feeding motivation. Similarly to other livestock species, such as pigs, a short duration of feeding may thwart the feeding motivation. That frustration predisposes cows to abnormal behaviour such as oral stereotypies. In addition, straw provision has been shown to increase cattle feeding and ruminating behaviour [36]. Unfortunately, we herein could not evaluate the individual cow ruminating activity due to far video recording distance, which was necessary to catch the whole pen view. Whether motivated exploration/eating straw bedding is a redirected or compensatory behaviour may not be elucidated. Either way, this environmental enrichment increased the ability of the animals to deal with behavioural and physiological challenges.

If we consider the sum of time eating the TMR and the time exploring and/or eating the straw bedding material (5.2, 5.5 and 6.0 h/day, in restricted PA, and maintenance PA and PI cows, respectively), these beef cows seemed to show a behavioural adjustment process of balancing intake capacity, or feeding motivation, by consuming low-quality straw bedding. This should be taken into account when designing experiments aiming to control the dietary supply.

Finally, the effect of some environmental conditions (e.g., access to resources, seasonal climatic conditions) and the social environment on time budget activity should not be ignored. Although not explored here, one could claim that the given space and feeding allowance in this study might contrast with previous studies where an increasing stocking density (or decreasing the area of the feeder per animal) altered the feeding behaviour [37] by challenging the access to resources. The effect of season on the time budget activity was not targeted in this study since the rest of the year the traditional livestock system is fully dependent on pasture (only indoors during winter due to pasture scarcity). Yet, summer is the most influential season on the daily budget of housed animals reported in the literature [38].

5. Conclusions

The restricted feeding level did not affect the time standing or lying, but it reduced the time eating TMR and increased the time exploring and/or eating straw bedding. Both breeds showed a similar daily activity budget, except the time for foraging straw bedding material that was lower in PA than in PI breed. Overall, lactating beef cows spent more time standing than lying, but their time idling occurred mostly while lying. This study provides the first step necessary for gathering knowledge on how different environmental factors affect housed suckler cows' behaviour. Further investigations are desirable to better understand the daily behavioural patterns of housed suckler cows, particularly regarding ad libitum feeding conditions and considering rumination activity.

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