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Short communication. Behavioural activities of two dairy cow genotypes (Holstein-Friesian *vs.* Jersey × Holstein-Friesian) in two milk production systems (grazing *vs.* confinement)

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Abstract

The aim of this work was to study the behavioural activities of two cow genotypes, Holstein-Friesian (HF) *vs.* Jersey × Holstein-Friesian (Jx), when managed within two production systems, a low inputs grazing (G) system *vs.* a high inputs confinement (C) system. Eighty spring calving cows (HF, n = 40 and Jx, n = 40), from AFBI Hillsborough (Northern Ireland) experimental dairy cattle, were randomly assigned to one of two production systems (G, n = 40 and C, n = 40) in a block design with a 2 × 2 factorial arrangement of four treatments (HF-G, HF-C, Jx-G and Jx-C). Cow behavioural activities (feeding, lying, standing and ruminating) were registered on three periods at 20-min intervals, between 16.00-22.00 h and 07.00-14.00 h. Average milk yields (kg cow^{-1} day^{-1}) were higher ($p < 0.001$) in the C system (27.0) than in the G system (20.1), with differences ($p < 0.001$) between the two cow genotypes (HF, 25.1 *vs.* Jx, 22.0 kg cow^{-1} day^{-1}). Milk production system showed an effect on cow behavioural activities. Animals on the G system spent more time ($p < 0.001$) grazing (522 min) than those on the C system spent feeding (173 min). Cows on the C system spent more time ($p < 0.001$) lying (C, 411 *vs.* G, 212 min), standing (C, 236 *vs.* G, 85 min) and ruminating (C, 244 *vs.* G, 141 min) than those on the G system. There were differences between periods for time spent lying ($p < 0.001$), feeding ($p < 0.05$) and ruminating ($p < 0.001$), while time spent standing did not differ between periods. Cow genotype had no effect on any of the behavioural activities.

Additional key words: breed; cow behaviour; dairy cattle; feeding system.

Different feeding strategies for milk production exist in Europe, ranging from low inputs grazing systems (G, based on fresh grass as the main food ingredient of cows' diet) to high inputs confinement systems (C, based on high levels of supplementation with silage and concentrate). There are significant differences in inputs cost, labour complexity, nutrient management, milk outputs and environmental impact within these contrasting production systems (Ferris *et al.*, 2011). Nevertheless, the effect of these two production systems on cow behaviour has not been extensively examined.

Until recently pure Holstein-Friesian (HF) cows have been exclusively selected by farmers as the best option for high inputs C systems to consider milk performance and cow conformation as the predominant breeding goal traits. However, it is now possible to achieve high levels of pasture dry matter intake (PDMI) by pure HF cows in low inputs G systems (Dillon *et al.*, 2006) combining low pre-grazing herbage mass levels with high daily herbage allowance levels (Roca-Fernández *et al.*, 2011). Also improvements in cows' genetic merit have made feasible to obtain high milk outputs from pure HF grazing cows at different lactation stage by using well managed pasture-based milk production systems with low levels of silage and concentrate supplementation (Roca-Fernández *et al.*, 2012). Nevertheless,

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Abbreviations used: BCS (body condition score); BW (body weight); C (confinement); DIM (days in milk); DM (dry matter); G (grazing); Gt (cow genotype); HF (Holstein-Friesian); Jx (Jersey × Holstein-Friesian); MY (milk yield); PDMI (pasture dry matter intake); P1 (period 1); P2 (period 2); P3 (period 3); Sys (milk production system); TMR (total mixed ration).

selection programs for milk production efficiency within pure HF cows as the dominant breed have led to a decline in functional traits (Heins *et al.*, 2006) and have prompted an interest in crossbreeding and the place of alternative breeds (Peyraud *et al.*, 2010). Ferris *et al.* (2011) have reported improved levels of fertility, longevity, health and milk composition in crossbred Jersey × Holstein-Friesian (Jx) cows compared to pure HF cows in systems of high concentrate inputs. Furthermore, they have demonstrated that crossbred Jx cows competed well with pure HF cows in systems of low concentrate inputs due to higher milk solids yield. However, there is lack of research comparing cow behaviour in grazing *vs.* confinement milk production systems (O'Connell *et al.*, 1989) for different breeds (Heins *et al.*, 2006). The aim of our work was to study the behavioural activities of two cow genotypes when managed within two milk production systems.

The study was conducted at Agri-Food and Bioscience Institute (AFBI) in Hillsborough, Co. Down, Northern Ireland (54° 5' N; 6° 1' W) from July 27 to September 4 in 2009. Mean daily temperatures (9.4°C) in 2009 were in line with those of the last 10-years. July and August were the hottest months (14.8°C) in 2009, with the highest number of sunshine hours (4.7 h). Total monthly rainfall was greater in August (+17.0 mm) compared to July (77.9 mm) in 2009, but similar to the last 10-years average. Total rainfall during the behavioural experimental time was of 118.9 mm.

The trial studied the behavioural activities of two cow genotypes (n = 80), Holstein-Friesian (HF, n = 40) *vs.* Jersey × Holstein-Friesian (Jx, n = 40), when managed within two contrasting milk production systems, a low inputs grazing system (G, n = 40) *vs.* a high inputs confinement system (C, n = 40). All animals calved in spring. A randomized block design with a 2 × 2 factorial arrangement of treatments was performed using primiparous (n = 20; 5 per treatment) and multiparous (n = 60; 15 per treatment) cows. The following four treatments were established in four separately farmlets (n = 20): HF-G (Holstein-Friesian cows at grazing), HF-C (Holstein-Friesian cows in confinement), Jx-G (Jersey × Holstein-Friesian cows at grazing) and Jx-C (Jersey × Holstein-Friesian in confinement).

On the low inputs G system, a total area of 8.4 ha sown with perennial ryegrass (*Lolium perenne* L.) was required for the study using 4.2 ha for each of the HF and Jx groups. The core grazing area comprised 21-day paddocks (0.21 ha each) for each treatment. A flexible rotational grazing system was adopted with fresh herbage allocated daily after p.m. milking (according to the number of cows in each group and pre-grazing herbage mass), so as to achieve a target residual sward height of 55 mm for each of the HF and Jx groups. Mean grazing season stocking rate for both genotypes was 4.4 cows ha^{-1}. Cows were offered whole paddocks during each 24-h. Total N fertilizer application was of 240 kg N ha^{-1} split in eight occasions (35, 45, 30, 30, 30, 25, 25 and 20 kg N ha^{-1}).

Pre- and post-grazing sward heights were measured daily within the grazing area for each cow genotype (40 measurements in a "W" formation) using a rising plate meter (Jenquip, Feilding, New Zealand). In addition, on one occasion each week ten locations were selected across the grazing areas (representing a range of herbage heights, from immediate post-grazing to immediately pre-grazing) and sward height was measured within a 0.36 m^2 quadrat (60 cm × 60 cm) using a rising plate meter (four drops per quadrat). Herbage within each quadrat was subsequently cut to ground level using battery operates hand shearers (Gardina Accu 6; Kress and Kastner, Weiterstadt, Germany), the weight of herbage was recorded and the DM content of the herbage was determined. At the end of the grazing season mean sward height (cm) and the associated herbage mass (kg DM ha^{-1}) within each quadrat were used to develop a linear relationship (Ferris *et al.*, 2011): Herbage mass = (Herbage height × 341.1) + 94.72. This equation was used retrospectively to determine pre- and post-grazing herbage mass within each paddock on a daily basis (based on daily pre- and post-grazing sward heights), with PDMI of each cow genotype group calculated as the difference between these two values. A mean PDMI was then calculated for the grazing season for each cow genotype.

On the high inputs C system, cows were confined and split into the two genotypes with each group being offered *ad libitum* a total mixed ration (TMR) (grass silage to concentrate, 50:50 DM). Grass silage offered was produced from primary re-growth herbages (mean harvest date July 10) harvested from predominantly perennial ryegrass (*Lolium perenne* L.) based swards. The ingredient composition of the concentrate offered (kg $tonne^{-1}$ DM) was as follows: barley (150), maize meal (150), sugar beet pulp (150), citrus pulp (150), soya bean meal (260), rape seed meal (80), megalac (20), calcined magnesite (5), molaferm (10), minerals and vitamins (25). In addition, 0.5 kg cow^{-1} of this concentrate was offered to each genotype at each production system in the parlour during each milking. Cows accessed their feed via six Calan gate feeding boxes (American Calan, Northwood, NH, USA) with each Calan gate linked to an automatic cow identification system, allowing cows to gain access to feed boxes mounted on weigh scales (Griffith Elder, Bury St Edmunds, UK). This system allowed individual cow food intakes to be recorded. Total DM intake was determined taking into account both TMR ingredients (grass silage and concentrate). The difference of weight between food offered and food eaten by cows using the Calan gates feeding system was used for determining the amount of food eaten by each cow independently. Each day uneaten food was removed from the feed boxes and replaced with fresh feed offered *ad libitum* at proportionately 1.1 of the previous day intake. Grazing and confined cows did not have access to food between 05.00-07.00 h and 14.00-16.00 h at milking time. In addition, cows on the C system did not have access to food between 09.00 h and 10.00 h when feed refusals were removed and replaced with fresh feed. The flooring of the aisle was cleaned by automatic scrapers six times daily. Cows were confined in pens containing 24 free-stalls deep bedded. There were two drinking troughs with water constantly available.

Throughout the grazing period herbage pluck samples were taken weekly from each of the two genotype grazing areas (at 20 random locations) and then dried overnight at 85°C for DM and crude protein determination. In addition, a fresh sample of grass was analyzed each week for metabolisable energy content estimation by NIRS System™ 6500. Chemical composition of TMR ingredients was determined as described Ferris *et al.* (2011). Body weight (BW) was recorded twice daily after milkings with an average calculated for each week. Body condition score (BCS) was scored weekly by two trained operators on alternate weeks using a five point scale (Edmonson *et al.*, 1989), where 1 = emaciated and 5 = extremely fat. Daily milk yields (MY) (kg cow^{-1} day^{-1}) were recorded at each milking. Milk protein and fat content (g kg^{-1}) were determined weekly from two consecutive milkings, with a.m. and p.m. samples analyzed separately. The concentration of milk constituents was determined by MilkoScan System™ Model FT 120, Foss Ltd., Warrington, UK.

On three occasions during six weeks, divided in three periods of two weeks (P1, end July; P2, middle August; P3, end August), each group of cows was observed at 20 min intervals between 16.00-22.00 h and 07.00-14.00 h by the same operator. The behaviour of each cow was recorded as follows: feeding, lying or standing (including walking and drinking). Ruminating activity was also recorded at the same time. The total time that each cow spent in each of these behavioural activities was calculated for each observation period to obtain daily time dairy cow budget. On one occasion during the observation cow behavioral trial (23-24 August), the grazing behaviour of 14 cows of each cow genotype was measured as reported Ferris *et al.* (2011) using grazing behaviour recorders. Seven cows from each cow genotype group were fitted with the recorders for a 23 h, starting after evening milking, with the process repeated the following day on a further seven cows. These recorders measured all jaw movements, with these data analyzed using "Graze" analysis software. Behaviors identified included: grazing and ruminating time (minutes day^{-1}), number of grazing and ruminating bouts, number of grazing bites, number of grazing and ruminating mastications.

Statistical analysis was carried out using REML analysis by Genstat. Sward and animal measurements and cow behavioural activities were performed using a 2 × 2 factorial design (2 cow genotypes and 2 production systems), with repeated measures (3 periods), by the model:

$$Y_{ijkl} = \mu + H_i + D_j + P_k + W_l\,(P_k) + H_i \times D_j + e_{ijkl},$$

where: Y_{ijkl} represents the response of sward or animal k to cow genotype i and milk production system j; μ is the mean; H_i is the cow genotype ($i = 1$, Holstein-Friesian and 2, Jersey × Holstein-Friesian); D_j is the milk production system ($j = 1$, grazing and 2, confinement); P_k is the period ($k = 1$ to 3); $W_l\,(P_k)$ is the week within period ($l = 1$ to 6); $H_i \times D_j$ is the interaction between dairy cow genotype and milk production system; e_{ijkl} is the residual error term.

Average rotation length for both cow genotypes in the G system was of 22 days. Total DM intake was lower in the G system (16.3 kg DM cow^{-1} day^{-1}) than in the C system (20.3 kg DM cow^{-1} day^{-1}). Mean pre- and post-grazing sward heights were of 10.3 and 6.1 cm for the HF cows and 10.0 and 5.9 cm for the Jx cows, respectively. Pre-grazing herbage mass at ground level was of 3,608 and 3,506 kg DM ha^{-1} for the HF and the Jx cows, respectively. Herbage grazed by both cow genotypes showed a mean crude protein and metabolic energy content in DM basis of 193 g kg^{-1} and 11.6 MJ kg^{-1}, respectively. Grass silage offered to cows in the C system showed a DM content ranging from 229 to 382 g kg^{-1} and a crude protein content ranging from

123 to 150 g kg^{-1} DM. Concentrate fed by cows in the C and G system had a mean crude protein content ranging from 204 to 180 g kg^{-1} DM.

On average, cows in the C system showed higher ($p < 0.001$) MY (+6.9 kg cow^{-1} day^{-1}) than those in the G system (20.1 kg cow^{-1} day^{-1}). The HF cows (+3.1 kg cow^{-1} day^{-1}) showed higher ($p < 0.01$) MY compared to the Jx cows (22.0 kg cow^{-1} day^{-1}). An interaction between cow genotype and milk production system was observed for MY but not for milk constituents. The Jx cows showed higher milk protein (g kg^{-1}) ($p < 0.05$, +1.9) and fat content (g kg^{-1}) ($p < 0.01$, +4.2) than the HF cows (35.7 and 44.4 g kg^{-1}, respectively). There were no significant differences between milk production systems for milk protein and fat content. Cows in the C system were heavier ($p < 0.001$, + 83 kg), in terms of BW, than those in the G system (482 kg). The Jx cows were lighter ($p < 0.001$, –58 kg) than the HF cows (552 kg). Animals in the G system showed lower ($p < 0.001$, –0.41) BCS than those in the C system (2.67). The Jx cows had higher ($p < 0.001$, +0.10) BCS than the HF cows (2.42).

Scanning of cow behavioural activities commenced when animals were on average 161 days in milk (DIM). Time spent lying ($p < 0.001$), feeding ($p < 0.01$) and ruminating ($p < 0.001$) differed between periods, while time spent standing did not show any difference (Table 1). Grazing cows spent more time lying (+53 min) and ruminating (+21 min) in the P3 than in the P1 (289 and 186 min, respectively). None of the behavioural activities recorded were affected by cow genotype ($p > 0.05$). Confined cows spent more time standing and ruminating ($p < 0.001$) compared to those on the grazing system, while cows at pasture spent more time grazing than confined spent feeding ($p < 0.001$). In Fig. 1 within both cow genotypes the main grazing bouts occurred after each milking (Fig. 1a and 1b), being more prolonged the evening than the morning bout. The percentage of cows feeding indoors remained relatively constant throughout the day, except for the time prior to fresh feed was offered (Fig. 1c and 1d). The main lying time in the grazing cows was after morning grazing bout was finished (09.00-11.00 h), while in the confined cows was after morning milking (07.00-10.00 h). In terms of time spent by animals in different activities, cows in the G system spent 25% lying, 68% grazing and 7% standing while cows in the C system spent 49% lying, 22% feeding and 29% standing. Ruminating represented 15% on grazing cows while 28% on confined cows.

Table 1. Effect of dairy cow genotype (Gt)[1] and milk production system (Sys)[2] on cow' behavioral activities

Time (min)	P[3]	Treatments				P[3]		Gt		Sys		P×Gt×Sys	
		HF		Jx		SEM[4]	Sig.[5]	SEM	Sig.	SEM	Sig.	SEM	Sig.
		G	C	G	C								
Lying	1	144	409	162	442								
	2	214	407	212	383								
	3	302	412	240	413								
	1-3	220	409	205	413	25.4	***	22.5	NS	22.5	***	24.1	**
Standing	1	117	250	116	209								
	2	96	230	62	253								
	3	55	235	67	242								
	1-3	89	238	82	235	24.7	NS	22.7	NS	22.7	***	23.8	**
Feeding	1	560	170	547	172								
	2	506	180	544	181								
	3	465	176	514	164								
	1-3	510	175	535	172	17.0	**	16.4	NS	16.4	***	16.8	NS
Ruminating	1	114	223	150	257								
	2	121	256	117	240								
	3	237	251	184	157								
	1-3	140	239	142	249	15.8	***	15.2	NS	15.2	***	15.6	NS

[1] Cow genotype (Gt): HF (Holstein-Friesian) *vs*. Jx (Jersey × Holstein-Friesian). [2] Milk production system (Sys): G (Grazing) *vs*. C (Confinement). [3] Period (P): 1 (end July), 2 (middle August) and 3 (end August). [4] SEM: standard error of the mean. [5] Sig.: significance. *** $p < 0.001$; ** $p < 0.01$; NS: not significant differences ($p > 0.05$).

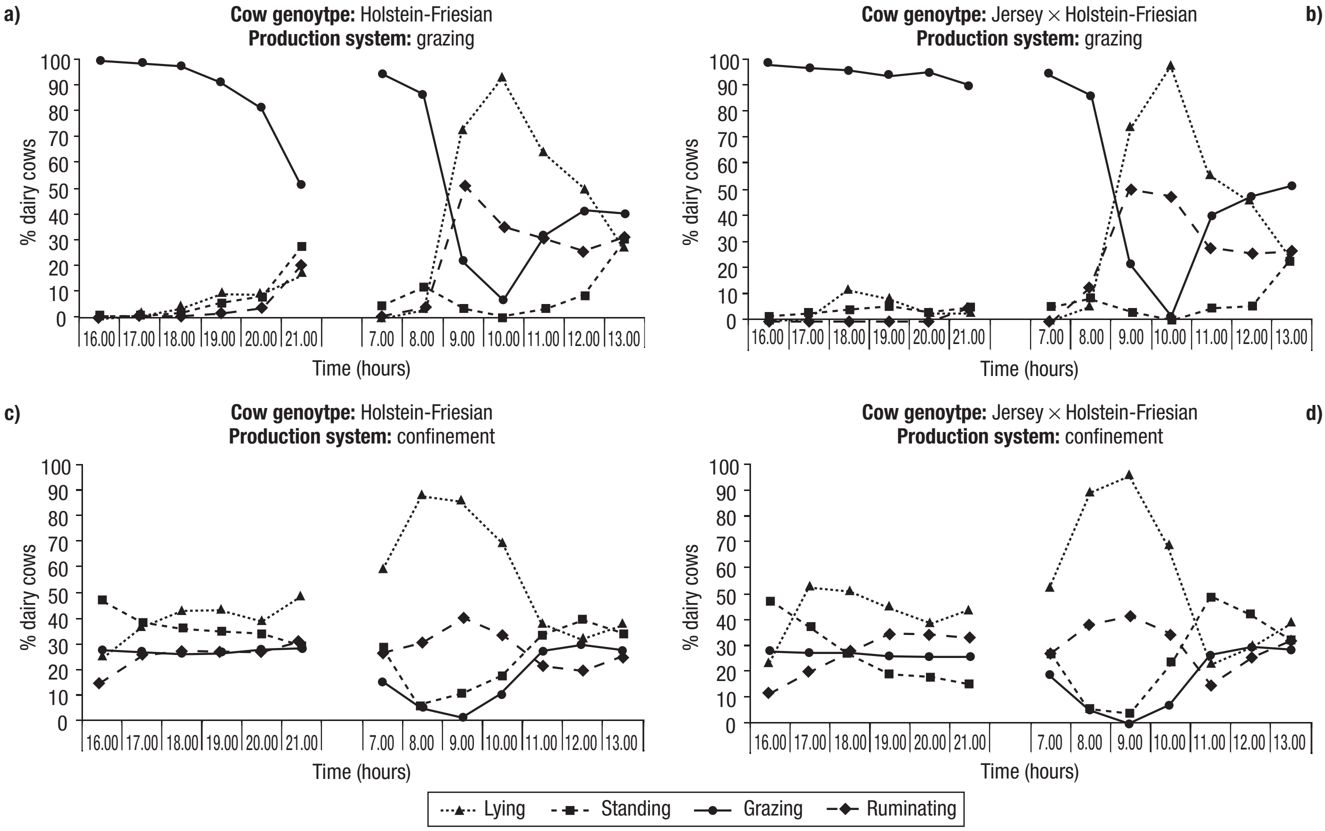

Figure 1. Percentage of dairy cows within each group involved in a range of behavioural activities.

Data from the whole lactation of the two cow genotypes for the two production systems reported by Ferris *et al.* (2011) showed that the HF cows produced more milk ($p < 0.01$, +963 kg cow^{-1} year^{-1}) than the Jx cows (6,701 kg cow^{-1} year^{-1}). Cows in the C system produced more milk ($p < 0.01$, +2,127 kg cow^{-1} year^{-1}) than in the G system (6,119 kg cow^{-1} year^{-1}). This in line with our results due to the highest milk performance was reached by the HF compared to the Jx cows. Ferris *et al.* (2011) also pointed the highest MY potential of the HF cows in either production system. In fact, despite there was no difference on total DM intake between cow genotypes milk responses were different. The Jx cows managed in the C system had similar total DM intake (20.1 kg DM cow^{-1} day^{-1}) to the HF cows (20.5 kg DM cow^{-1} day^{-1}) but lower MY and higher protein and fat content were reached by the Jx cows compared to the HF cows. The HF cows (14.8 kg DM cow^{-1} day^{-1}) managed in the G system had also similar PDMI to the Jx cows (15.1 kg DM cow^{-1} day^{-1}) but higher MY and lower protein and fat content were achieved by the HF cows compared to the Jx cows. On average milk protein and fat content for the whole lactation were higher ($p < 0.01$) in the Jx cows (36.4 and 47.6 g kg^{-1}, respectively) than in the HF cows (33.8 and 43.4 g kg^{-1}, respectively) without differences between the two production systems. The highest concentration of protein and fat in milk from the crossbred Jx cows is usually associated to the Jersey breed due to its capacity to increase the levels of these milk constituents (Ferris *et al.*, 2011). There was no effect of cow genotype on corrected milk solids yield per lactation (HF-G, 6,393; Jx-G, 6,436; HF-C, 9,277 and Jx-C, 8,235 kg year^{-1}, respectively) showing the results that the Jx cows can compete efficiently with the HF cows in both production systems. However, corrected milk solids yield per lactation was higher ($p < 0.001$) in the C system (8,756 kg year^{-1}) than in the G system (6,415 kg year^{-1}) pointing the potential of the HF cows to respond efficiently to higher concentrate feed levels than the Jx cows (Ferris *et al.*, 2011).

In relation to the behavioural activities of grazing cattle, the two cow genotypes did not differ in terms of time spent feeding, number of feeding bouts day^{-1} or the average duration of each feeding bout. Measurements took on the grazing system pointed that total

DM intake did not differ, even though the HF cows weighed approximately 70 kg more than the Jx cows. While the Jx cows consumed less herbage per min, due to their tendency to have lower intakes per bite, they grazed for longer each day and as such had significantly more grazing bites day^{-1} than the HF cows. In addition, although they had fewer grazing bouts day^{-1}, these bouts were longer. Thus, by modifying their grazing behaviour, *i.e.* altering the number of daily meals and the average meal size (length × rate of eating), the Jx cows were able to adjust daily DM intake achieving similar PDMI as the HF cows (Grant & Albright, 2000). In our trial, all cows did on average 5 meals in the 13 h of observation, but the length of the bout was higher in cows for the G system (523 min, with 26.2 times of 20 min) than in cows for the C system (174 min, with 8.7 times of 20 min) without any differences between the two cow genotypes, with an increase in the number of cows present at the feed barrier immediately following the morning delivery of fresh feed and milking. When a competitive situation exists at the feed barrier, dominant cows typically spend more total time feeding than cows of lower social rank, resulting in greater total DM intake (Grant & Albright, 2001). As competition per feeder increased, cows exhibited shorter average feeding times and accelerated eating rates at the feed barrier as happened in our trial with the confined groups. DeVries *et al.* (2005) found that by increasing the number of times feed was delivered low ranking cows were not displaced as often, which indicates feed availability has an impact on feeding related aggressive behaviour. Thus, in order to maximize voluntary DM intake, provision of both feed and space is necessary for both cow genotypes in the confinement system. Likewise, proper animal grouping strategies within dairy herds reduce competition for food at the feed barrier and improve intake by providing fresh feed every 24 hours and promoting numerous small meals daily (Grant & Albright, 2000) as happened in our trial with the confined groups. The accessibility of feed might be more important than the actual amount of nutrients provided, therefore, cow space and density, distribution of feed and watering facilities all influence total DM intake. Feed intake and milk production is generally improved when cows are allowed access to feed when they want to eat (Grant & Albright, 2001). Irregular or infrequent feeding and excessive walking from the milking parlour appeared to have negative effect on cow behaviour and welfare. In our trial, confined cows spent 151 min more standing than grazing cows.

Taking into account that management imposed on cows do not have to prevent or discourage them from obtaining adequate rest and nutrition (Drissler *et al.*, 2005). In our trial, cows on the G system spent 3, 9 and 1 h lying, feeding and standing while cows on the C system spent 6, 3 and 4 h lying, feeding and standing. Ruminating represented 2 h for the G system and 4 h for the C system. Our results agree with Grant & Albright (2000) for confined cows in a free-stall system with 10 h per day of lying, 3-5 h of feeding and 7-10 h of ruminating instead of the fact that in our trial we have lower daily time observation. Furthermore, Tucker & Weary (2004) reported that lying times is increased with the amount of bedding provided and softer bedding corresponds to longer lying times. In our trial, confined cows lied daily for a long time due to high quality of bedding provided and the low rate of lying time on the G system might be explained by the fact that during diurnal time cows preferred to graze in order to satisfy their feeding needs. In our confined groups, limitations in access to food due to insufficient Calan gates would make cows lying and standing more than feeding.

Our trial took place during middle to end of summer when sunrise and sunset occurred in the P1 at 06.00 h and 22.00 h and in the P3 at 07.00 h and 21.00 h, respectively. Large variations in daily time budget of dairy cows were observed between the three periods of observation for lying, feeding and standing in the grazing system. However, in the confinement system no influence of the number of daylight hours was observed in dairy cow behavioural activities due to the presence of artificial light. It seems that grazing cows were lying and ruminating more during the P3 than in the P1 due to a decrease on grazing activity. Probably, this might be explained by a reduction in the number of sunshine hours and more intensive grazing activity with a decrease in the length of the grazing bout.

Our study examined the importance of comparing milk responses and cow behavioral activities of two production systems (a low inputs grazing system *vs.* a high inputs confinement system) and two cow genotypes (Holstein-Friesian *vs.* Jersey crossbred). Feeding system influenced highly on total DM intake, milk outputs and cow behaviour. Nevertheless, in our case cow genotype did not affect total DM intake in grazing or confined animals. Jersey crossbred cows appeared to have a higher grazing drive evidenced, by their increased grazing intensity and fewer grazing bouts, allowing similar PDMI to that reached by Holstein-

Friesian cows. Milk responses were different in both production systems with higher MY and lower protein and fat content in the HF cows than in the Jx cows. However, none of the behavioral activities were affected by cow genotype. Time spent lying, standing and ruminating were higher in the confined cows than in the grazing cows. Grazing cows spent more time feeding at sunlight hours than confined cows. In conclusion, cattle usually consume feed efficiently whether is grazing or confined and independently of selected cow genotype. Cows normally adapt their daily time budget to the chosen milk production system in order to satisfy their feeding, lying, standing and ruminating needs. Feed accessibility within the group when animal desires to feed may be the most important factor for the attainment of maximum total DM intake, productivity and well-being of dairy cows at grazing or confined whatever the selected genotype.

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