Eliminative behaviour of dairy cows *Lindsay Whistance*

Introduction

Faeces plays a prominant role in the transmission of three major diseases in housed cows, namely, lameness, mastitis and Johne's disease (Amory *et al.*, 2006; Hughes, 1999; Anon., 2002). Cows show no evidence of latrine behaviour and because their eliminative patterns appear to be random, it is assumed that they have little control over it and that they make no attempt to avoid bodily contamination with excreta (e.g., Hafez and Schein, 1962). The cleanliness of housed cattle is therefore considered to be solely a management issue.

At pasture, cattle are known to strongly avoid grazing near dung patches where faeces and the surrounding contaminated grass act as reservoirs for parasites (Marten and Donker, 1964a;b). Michel (1955) found bovine grazing to be highly selective and, when tested, forage selected by cattle contained fewer lungworm larvae than random samples. An area of forage up to six times greater than that covered by faeces can be rejected (Phillips, 1993).

There appears to be an odd dichotomy between the well-documented strong aversion to grazing near faeces as a means of controlling parasite intake and the apparent lack of regard for bodily cleanliness when contamination with faeces also has real health consequences for the cow, suggesting that more research is required to understand if and why this dichotomy exists. Previous studies have looked at the posture of the cow when voiding (Aland *et al.*, 2002), the daily pattern of faeces deposition in different housing systems (Brantas, 1968; Seo *et al.*, 2003; Aland *et al.*, 2002; Hörning and Kramer, 2003), and their lying on clean, freshly-grazed grass when at pasture (Broom *et al.*, 1975). However, relatively little is yet known about whether cattle show any intentional avoidance of bodily contact with excreta or not, or whether there are any specific environmental, social or individual stimuli which influence eliminative behaviour.

The two main types of housing system in the UK are straw yards and cubicles with cubicle systems becoming an increasingly popular choice. Economic advantages of cubicles, compared to straw yards, include a reduction in space requirement per cow, a reduction in the amount of bedding used, a fully-mechanised system for slurry removal, less storage space required for clean and soiled bedding and fewer man hours required to maintain the system. However, the layout of a cubicle system, designed to limit the soiling of bedspace, also has a marked impact on several, unrelated behavioural patterns. For example, cubicles stop play behaviour (Fregonesi and Leaver, 2001), inhibit normal social behaviour (Philips and Schofield, 1994), increase aggressive interactions (Fregonesi and Leaver, 2002) and they provide an uneven distribution of facilities which affects subordinate individuals in particular (Galindo and Broom, 2000). Cubicles also lower comfort levels for cows when lying and rising (Hörning and Krämer, 2003), inhibit both oestrus behaviour (Fregonesi *et al.*, 2004) and post-oestrus recuperative lying (Phillips and Schofield, 1990) and they disturb temporal rumination patterns (O'Connell *et al.*, 1989), as well as herd synchronicity (Nielsen *et al.*, 1997).

The trend in dairy farming has been towards fewer, more efficient cows in larger herds which are kept in more mechanised and rationalised systems. But these systems, whilst placing less emphasis on the comfort of the individual cow or the maintenance of an harmonious social structure or herd synchronicity, have not resulted in a reduced disease incidence. To a degree they can, therefore, be considered to be inadequate as permanent/semi-permanent accommodation. Nevertheless, indoor confinement of cattle cannot be completely avoided because even if cows do not need to be housed in the wintertime for physiological reasons, it is still required to preserve and maintain pastureland and it is then logical for indoor systems to function well from a management point of view. However, we should be aiming to provide cattle with housing systems that allow for the expression of natural individual and social behaviour patterns. Since the control of environmental and bodily contamination of excreta is of high importance, the understanding of cow behaviour at the time of elimination seems pertinent to housing design and could enable the development or improvement of housing styles which facilitate cattle in controlling their own cleanliness levels to a greater degree and also reduce the negative impact of housing design on other, unrelated behaviour patterns.

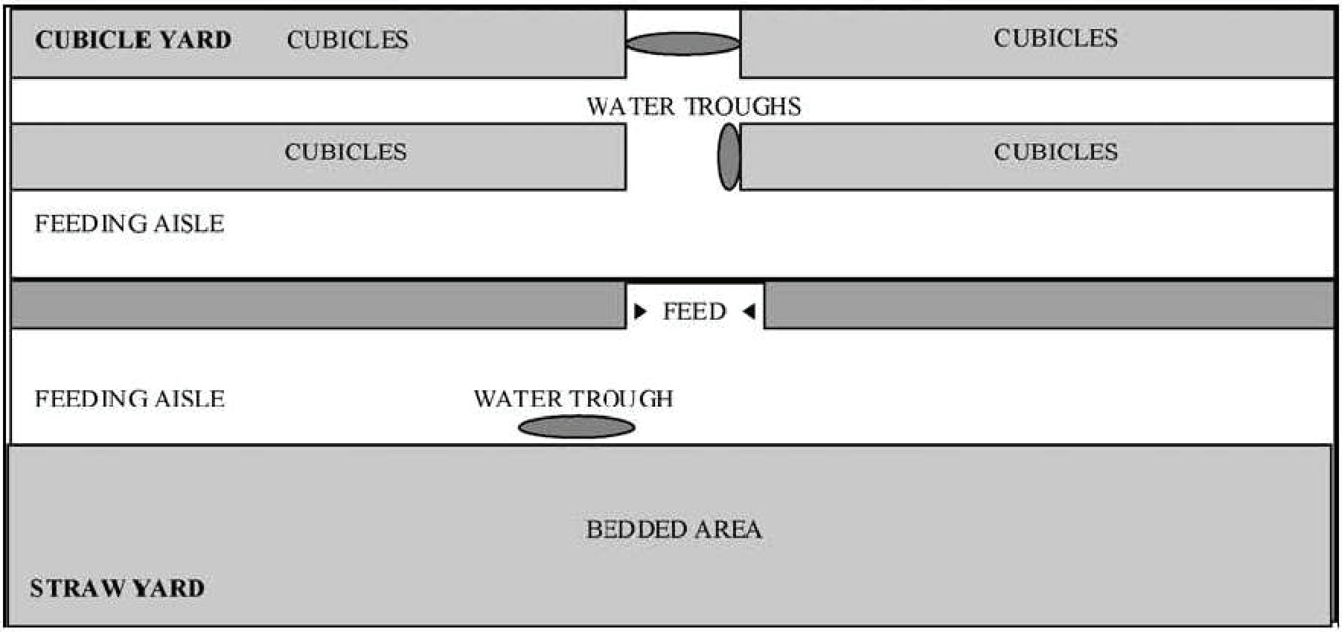
Detailed observations of eliminative behaviour are required in order to compile an ethogram and to determine whether there is any evidence of faeces and urine avoidance behaviour in outdoor cattle. Analysis of eliminative behaviour in the two most commonly used housing systems for dairy cattle in the UK, i.e., cubicle systems and straw yards, would help determine whether avoidance levels are affected and whether cattle adapt eliminative behaviour to indoor living conditions.

Study one: An investigation of potential differences in eliminative behaviour in high and low yielding dairy cows maintained in a straw yard or cubicle system

The aims of the first study were:-
to determine whether housed dairy cows show avoidance of freshly deposited faeces.
to assess whether housing type affects defaecation patterns, and
to measure the effects of yield level on defaecation behaviour within each housing system.

<u>1.1 Method</u>
The two main UK housing types were included in the study, namely a straw yard (S) and a cubicle system (C). High (H) and low (L) yielding cows were placed into four treatment groups, straw low, straw high, cubicle low and cubicle high, where the same housing unit was used for both yield groups (Fig. 1.1).

Fig. 1.1 A schematic diagram of the cubicle system and straw yard.



4 treatments: SL (n = 73); 13.8 $\pm$ 7.8 kg/d
SH (n = 72); 40.1 $\pm$ 13.5 kg/d
CL (n = 85); 17.8 $\pm$ 6.4 kg/d
CH (n = 93); 38.7 $\pm$ 7.5 kg/d

Yield difference was significant between high and low yield groups (ANOVA, $P<0.001$; Tukey's critical value = 3.63) but not within yield groups (Anderson-Darling Normality Test, $P<0.05$).

Each group was observed (round the clock) for six hours a day over four successive days, though not during the milking process. Each animal seen eliminating became the target animal for the duration of the behaviour (similar to the method of Weschler and Bachmann, 1998). Any cow that was observed to be about to defaecate had their behaviour classified as lying (L), standing (S) or walking (W) immediately before, during and after elimination. If the post-eliminative behaviour was only maintained for up to and including ten seconds the subsequent behaviour was also recorded.

Sequences of eliminative behaviour were then classified as showing (a) no avoidance of faeces, (b) incidental avoidance of faeces or (c) intentional avoidance of faeces. A standing cow avoids soiling her hindquarters by adopting the rounded back posture (Aland *et al.*, 2002) and a walking cow is removing herself from freshly deposited faeces, therefore, sequences were recorded as incidental avoidance when cows were walking or standing to eliminate and either moved away or remained standing after voiding but were also engaged in a second activity such as drinking or changing places at the feed bunk. Sequences were classified as intentional avoidance of faeces when cows stopped a specific behaviour to eliminate and moved away before resuming their pre-elimination behaviour and without engaging in a second activity. No avoidance of faeces was recorded where lying cows were lying down when voiding and remained lying after eliminating and where cows were standing to eliminate but did not move away before lying down.

All four treatment groups contained different numbers of cows and so prior to further statistical analysis, the total expression of each behaviour sequence was corrected by proportionately scaling down the totals of the larger groups so that they were equivalent to the totals of the group with the smallest number of animals within each test. Where housing effects were investigated, the data from high and low yielding cows were pooled. For goodness of fit, the G – test was used along with its associated Williams' correction factor.

1.2 Results

A total of 3438 expressions of defaecation behaviour were recorded for the 323 cows included in the study, averaging 10.64 instances recorded per cow. The location in each housing system of freshly-deposited dung was recorded (Fig. 1.2) and the total number of defaecations landing in the straw bed (851) was higher than those deposited directly in the cubicles (91; G_{adj} = 779.95; P < 0.001). Within the straw-housed groups, more faeces landed on the straw bed in total (851) than on concrete (760; G_{adj} = 5.14; P = 0.023). However, the concrete feeding passage, measured 208 m^2 compared to 572 m^2 for the bedded area, therefore, the rate of defaecation/m^2 was greater for the concrete passage at 3.65/m^2 than for the bedded area at 1.49/m^2 (G_{adj} = 4.0; P = 0.045). Cows housed in cubicles defaecated a total of 610 times in the concrete feed passageway (156 m^2) compared to a total of 1215 being deposited in the concrete cubicle aisle (114.4 m^2). The rate of defaecation/m^2 was therefore greater for the cubicle aisle (10.62/m^2) than for the feed passageway (3.91/m^2) (G_{adj} = 6.32; P = 0.012).

When sequences were classified as showing a) no avoidance of faeces, b) incidental avoidance of faeces or c) intentional avoidance of faeces (Table 1.1i), cows in both systems exhibited high levels of avoidance of faeces overall (G_{adj} = 3532.6; P = < 0.001). Between housing systems, however, (Table 1.1ii) cows in the straw yard groups showed both higher incidental and intentional avoidance of faeces b) and c) (P < 0.001), whilst cows housed in cubicles showed greater levels of no avoidance of faeces a) (P < 0.001). Within the straw yard, the high yield group (Table 1.1iii) displayed more incidental faeces-avoidance sequences (G_{adj} = 37.96; P = < 0.001) than did low yield cows. In the cubicle system (Table 1.1iv), both yield groups showed similar levels of no avoidance, incidental and intentional avoidance of faeces: (a) G_{adj} = 1.55; P = 0.210, (b) G_{adj} = 0.28; P = 0.594 and (c) G_{adj} = 0.36; P = < 0.550.

Table 1.1 Classification of the number of sequences of behaviour indicating intentional, incidental or no avoidance of faeces between cows in straw and cubicle systems and between high and low yield groups.

	No avoidance of faeces	Avoidance of faeces	G_{adj}	*P* value
(i) Housing type				
Straw yard (*n* = 145)	19	1591	-417.29	< 0.001
Cubicle yard (*n* = 178)	131	1697	-717.99	< 0.001
Straw yard <u>and</u> cubicle system	150	3288	3532.61	< 0.001

	Straw (*n* = 145)	Cubicles[a] (*n* = 178)	G_{adj}	*P* value
(ii) Behaviour category				
No avoidance	19	120	81.60	< 0.001
Incidental avoidance	1517	1308	15.45	< 0.001
Intentional avoidance	58	2	63.43	< 0.001

	High yield Straw (*n* = 72)	Low yield Straw (*n* = 73)	G_{adj}	*P* value
(iii) Behaviour category				
No avoidance	13	6	2.65	0.104
Incidental avoidance	882	642	37.96	< 0.001
Intentional avoidance	28	30	0.04	0.836

	High yield[a] Cubicles (*n* = 93)	Low yield Cubicles (*n* = 85)	G_{adj}	*P* value
(iv) Behaviour category				
No avoidance	69	55	1.55	0.213
Incidental avoidance	815	794	0.28	0.594
Intentional avoidance	1	2	0.36	0.550

(i and ii) indicate the interaction between housing type and behaviour category;
(iii and iv) indicate the interaction between yield and behaviour category.
[a] Values corrected for group size.

In all, thirty-three different sequences of behaviour were displayed at the time of defaecation and, for the purpose of this study, similar sequences were grouped and the data pooled (see Whistance *et al.*, 2007). The three most commonly expressed sequences for all cows were lSs, sSs and wSs which accounted for over half of all recorded events. Between cows in the two housing types, there was a highly significant difference in the expression of one behaviour in particular from each category of avoidance, namely lLl, wWw and lSwl (Table 1.2).

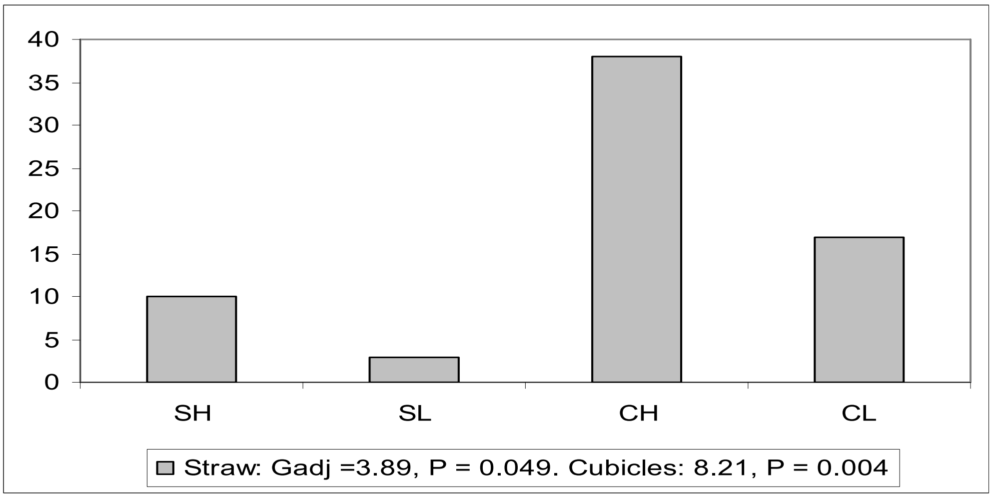
Table 1.2 Individual sequences of defaecation behaviour for cows housed in a straw yard or cubicle system, indicating intentional, incidental or no avoidance of faeces

Behaviour sequences[a]	Faecal avoidance[b]	Straw (*n* = 145)	Cubicles[c] (*n* = 178)	G_{adj}	*P* value
lLl	a	13	46	19.02	< 0.001
wWw	b	41	108	31.23	< 0.001
lSwl	c	58	2	63.43	< 0.001

[a] lowercase letters denote pre-and post defaecation behaviour and uppercase letters denote behaviour whilst defaecating.
[b] (a) sequence indicating no avoidance of faeces: (b) sequence indicating incidental avoidance of faeces; (c) sequence indicating an intentional avoidance of faeces.
[c] Values corrected for group size.

Comparing individual behaviour sequences of the high and low yielding cows in cubicles (Fig 1.2), the proportion in the high yielding group remaining lying throughout (lLl) was greater than in the low yielding group (G_{adj} = 8.21; P = 0.004). As with the cows housed in cubicles, cows in the high yielding group on straw showed a significant, but less marked, increase in the expression of lLl than the low yielding cows on straw (G_{adj} = 3.89; P = 0.049).

Fig 1.2. Expression of lLl over 24 h in high and low yielding cows in straw yards and cubicle systems



1.3 Discussion

The average rate of defaecation within each group recorded in this study, ranging from 9.4 - 12.8 defaecations/cow/day, corresponds with data from previous studies measuring total eliminations per day of 9 – 16 defaecations (Sahara *et al.*, 1990; Aland *et al.*, 2002). The rate of defaecation/m^2 for cows housed in cubicles was significantly greater for the cubicle aisle than for the feed passageway. This would suggest that cows were spending the majority of their time in the cubicle area of their housing. Konggaard (1983) found that dairy cows not engaged in eating or lying tended to congregate in the cubicle passageway. Within the groups housed in straw yards, more faeces landed on the straw bed in total than on concrete but the rate of defaecation/m^2 was more than two times greater for the concrete passage. These results are in accordance with the findings Seo *et al.* (2003) who noted that the frequency of defaecation was highest in the feeding area in straw yard systems. Rising more regularly to feed reduces the need to void immediately upon rising and, consequently, cows are more likely to move away from the bedded area before defaecating (Saitoh *et al.*, 2005).

Aland *et al.* (2002) stated that after cows have voided they take a few steps forward. Although the authors do not state under which conditions these observations were made, it is reasonable to assume that the behaviour was recorded from cows at pasture. In the present study, a significant number of cows in both housing systems remained static after voiding and, for groups SL, CH and CL, significantly more often than they moved forward, suggesting that both housing types strongly inhibited voluntary forward movement post elimination. However, cows in the SH group showed a greater level of forward movement post defaecation than the other three groups, suggesting a yield effect as well as a housing effect. The moving away from faeces when standing would suggest that high yield cows in the straw yard were more strongly motivated to avoid fresh faeces than low yield cows in the same environment. The reason for this is unclear, though may be linked to avoidance of disease.

The act of elimination is considered to be largely involuntary (Hafez and Schein, 1962; Albright and Arave, 1997, p.40) and a number of the sequences of behaviour recorded occurred whilst the cows were also engaged in other activities. For example, sSs was most often recorded whilst cows were eating at the feed trough and wWw mostly occurred when a cow moved from the feed passageway to the cubicle passageway. Cows move more quickly between resources when access to those resources is constrained (Munksgaard *et al.*, 2005). The behaviour sequences, classified as indicating incidental avoidance of faeces, do not indicate a clear intention to avoid faeces but may be indicative of a greater motivation to feed and drink or gain access to lying space (Metz, 1985; Phillips, 1998). However, a standing cow can avoid soiling her hindquarters by adopting the rounded back posture and a walking cow is also removing herself from freshly deposited faeces so that any further, and more obvious, avoidance may not be necessary.

Opportunities to move away from freshly deposited faeces differed with housing design. Those cows rising to defaecate before moving away in the straw yard all moved in a forward direction and consequently avoided contact with their faeces. Cows in cubicles, however, reversed out of the cubicles and subsequently stepped into the freshly deposited faeces, although a few cows were observed making an exaggerated first step with a hind leg, thereby avoiding contact. Cows housed in cubicles displayed sequences which exposed them to faecal contamination four times more often than groups in straw yards. Cows housed in the straw yard exhibited greater levels of sequences of 1) rising to defaecate and then moving forward and 2) defaecating then moving forward before lying down than did cows in the cubicle yard. The greater expression of these sequences may reflect both the higher level of comfort and greater ease of movement in straw yards where cows are more likely to intersperse lying time with feeding bouts and were consequently rising and lying more frequently each day (Hörning and Krämer, 2003). The cleanliness levels of the cows in straw yards were high during the study with none of the cows showing soiled body parts other than the lower leg. This would indicate that they were indeed capable of avoiding lying in the soiled areas of bedding.

The behaviour sequence lSwl suggests an intentional avoidance of contact with fresh faeces as lying behaviour was broken off for defaecation to occur and was then resumed shortly after the cow had moved away from the fresh faeces. Cows housed in the straw yard performed these sequences significantly more often, which again suggests that the straw yard system may have imposed fewer restrictions on faeces avoidance behaviour than did the cubicle system. The inability to move in a forward direction post defaecation, the reduced levels of comfort when rising and lying down (Hörning and Krämer, 2003) and a reluctance to vacate favoured lying spaces may all be contributory factors in discouraging the expression of faeces avoidance behaviour in cows housed in cubicles.

High yielding cows displayed a significant increase in the lLl sequence, irrespective of housing design. This would suggest that any motivation to avoid contamination with freshly deposited faeces by rising to defaecate was overridden by an increased need to lie and rest (Metz, 1985). However, the difference in the rate of expression of lLl between high and low yielding groups within housing systems was greater in cows in cubicles which implies that housing design further exacerbated the reluctance of high yielding cows to always rise before defaecating. The high yielding cows in the straw yard system were also more likely to void prior to lying down and showed significantly higher levels of avoidance on these occasions, compared to high yielding cows in the cubicle system, implying that the straw yard provided these cows with some behavioural flexibility when avoiding excreta which was not available to cows in the cubicle yard.

The results of this study suggest that the design of cubicles is successful in reducing the level of faeces and urine being deposited directly in bedded areas, although, once a cubicle is soiled a cow is not then able to avoid contact with faeces or urine without avoiding the cubicle altogether. This may be difficult if few, or no spare cubicles are available, in which case, the prompt cleaning of cubicles becomes essential if herd hygiene and cleanliness levels are to be maintained. The repertoire of behaviours is perhaps too complex to simply compare one sequence directly with another but, overall, cows housed in straw yards were more likely to show an avoidance of contact with faeces before lying down and were more likely to interrupt lying to void. Therefore, the successful design of cubicle systems in controlling where faeces lands also inhibits the dairy cow's ability to express inherent avoidance behaviours. This suggests that cubicle housing, designed primarily to ease management procedures, is not an optimum housing system for the cow herself. It is suggested that cows in cubicles are being forced into cleanliness rather than enabled to maintain personal behaviour patterns and that this forced cleanliness also affects other unrelated sequences of behaviours such as social patterns, lying time and behavioural synchrony (e.g., Galindo and Broom, 2000; Fregonesi and Leaver, 2001; 2002). This may then be in conflict with number four of the five freedoms namely, freedom to express normal behaviour (FAWC, 1997).

1.4 Conclusions

The high levels of avoidance faeces recorded in this study challenges the traditional assumption that cows do not avoid bodily contact with freshly deposited faeces and urine. The dairy cows observed in this study showed a large range of eliminative behaviour patterns. Some of these sequences showed a voluntary and intentional avoidance of bodily contact with fresh excreta whilst the majority indicated a more incidental avoidance. Cows in the straw yard showed much higher levels of intentional and incidental avoidance of excreta than did cubicle housed cows, whereas cows housed in cubicles remained lying to defaecate significantly more often, suggesting that housing design influences a cow's ability to avoid contact with fresh faeces. The greater incidence of high yield cows remaining lying whilst voiding, independent of housing system, may be an indication of their greater motivation to lie and rest.

Study two: An investigation of potential differences in eliminative behaviour and activity in high and low yielding dairy cows at pasture

The aim of this study was to investigate the eliminative behaviour of dairy cows at pasture, with the intention of improving knowledge of cow behaviour, when unrestricted by housing design.

2.1 Method

Sequences of walking (W), standing (S) and lying (L) were again recorded around each elimination event. Activities around an act of elimination were also noted for grazing cows to determine whether the behaviour that they were engaged in when eliminating had an effect upon their behavioural sequence. Static activities: lying (l), loafing (lo) and grazing (g); Active activities: moving to a different area of the field (mf), catching up with herd (cu) and walking to drinking trough (td). Twenty high yield cows (mean kg/d 38.0, range 30.6 - 51.2, SD 6.5) and twenty low yield cows (mean kg/d 17.0, range 9.4 - 21.6, SD 3.7) were selected as study animals (T-test: T-value 12.53, P < 0.001) and balanced for parity (total mean parity 3.4, SD 2.2; T-test: T-value -0.07, P = 0.945). The high and low yielding groups were each given access to approximately 10 hectares of rye-grass/clover pasture day and night and offered TMR after each milking period. For each group, six hours of behaviour were recorded each day (during daylight hours) over four consecutive days. The G-test, with its associated William's correction factor, was used for data analysis.

2.2 Results

The average number of defaecations recorded per cow were high yield group (GH) 10.4 and low yield group (GL) 11.5. None of the sequences recorded could be classified as 'no avoidance of faeces' using the stated criteria. The majority of elimination events for both yield groups indicated incidental avoidance of faeces with no difference between high and low yield groups (G_{adj} 0.53, $P = 0.466$). There was a trend, however, for the low yield group to show greater levels of intentional avoidance of faeces (G_{adj} 3.29, $P = 0.070$). The most frequently expressed sequences in both yield groups were sSws and wSws (GH = 0.26 and GL = 0.29) and lSw and lSws (GH = 0.23 and GL = 0.20).

When the data from the two groups were pooled, the cows (n = 40) performed sequences of standing to defaecate and then moving forward more often than sequences where they either stood to defaecate and remained standing (G_{adj} 166.27, $P < 0.001$) or walked whilst defaecating (G_{adj} 119.55, $P < 0.001$). Standing to defaecate and then moving at least a few paces forward, involved 18 of the 31 sequences which were expressed 170 times out of 208 for GH (G_{adj} 90.34, $P < 0.001$) and 196 of 230 for GL (G_{adj} 125.87, $P < 0.001$). Defaecating prior to lying down was expressed far less frequently in both groups than voiding after getting up sequences (G_{adj} 178.75, $P < 0.001$). Of the defaecation sequences recorded, eight included cows walking whilst defaecating. The levels of expression over the 24 hours studied were, standing whilst defaecating = 383 and walking whilst defaecating = 54 (G_{adj} 278.64, $P < 0.001$).

The activity of cows before, during and after elimination was categorised as (i) walking or (ii) standing to defaecate when cows were actively moving forward a) before, b) after, c) before and after defaecating and d) static before and after defaecation (Table 2.1). It should be noted that static activity refers to the activities in which cows were not actively moving forward; it does not indicate whether or not cows moved a few paces away from their freshly deposited faeces. The most predominant group of activity sequences for standing to defaecate was static activities before and after defaecation (n=317). For walking whilst defaecating, the predominant group of activity sequences was static activity before defaecating and actively moving forward after defaecating (n=24). When active before and after defaecating, cows were as likely to walk as stand to defaecate (G_{adj} 0.13, $P = 0.72$).

Table 2.1 Cows at pasture either standing or walking to defaecate within activity categories

Both groups (*n* = 40)	Walking	Standing	G_{adj}	***P* value**
Active before and static after defaecating	ai	aii		
	1	6	3.70	0.05
Static before and active after defaecating	bi	bii		
	24	43	5.42	0.02
Active before and after defaecating	ci	cii		
	14	16	0.13	0.72
Static before and after defaecating	di	dii		
	15	317	337.52	< 0.001

Overall, the predominant activity sequence expressed was grazing before and after defaecation (gSg), (Table 2.2). Low yield cows were more likely to rise to defaecate followed by grazing activity (G_{adj} 6.93, P = 0.01) than high yield cows, whereas the latter were more likely to rise to defaecate followed by loafing activity (G_{adj} 4.96, P = 0.03).

Table 2.2 Expression of individual sequences of activity most commonly expressed by high and low yield groups

Activities before, during and after defaecation.[1]	**High yield** (*n* = 20)	**Low yield** (*n* = 20)	G_{adj}	***P* value**
Standing to defaecate:				
dii) gSg	54	60	0.31	0.58
lSg	27	50	6.93	0.01
lSlo	34	18	4.96	0.03
loSlo	19	12	1.57	0.21
bii) lSmf	11	6	1.45	0.23
lScu	9	9	0	1
Walking whilst defaecating:				
bi) lWcu	6	6	0	1
lWmf	6	1	3.70	0.05
ci) mfWmf	2	5	1.24	0.27
tdWtd	2	5	1.24	0.27
di) gWg	4	3	0.13	0.72

[1]Uppercase letters denote walking (W) or standing (S) to defaecate. Lower case letters denote pre and post defaecation activities graze (g), lie (l), loaf (lo), move to different area of field (mf), catch up with herd (cu) and go to drink (td).

All activity sequences where cows expressed both walking and standing to defaecate were then compared. Where no differences were found between walking or standing to void, the most commonly expressed sequences of activities were lWcu (G_{adj} 1.19, P = 0.28) followed by mfWmf (G_{adj} 0, P = 1) and tdWtd (G_{adj} 0.07, P = 0.79).

2.3 Discussion

Cows at pasture exhibited 32 different sequences of defaecation behaviour. The most frequently expressed defaecation sequences were sSws, wSws, lSw and lSws which accounted for almost half of all recorded incidences for the 40 cows included in the study and yield status had no effect on their expression. These four predominant sequences, along with all other sequences in which cows stood to defaecate and then moved forward accounted for five out of every six incidences recorded. This general pattern of behaviour indicates that standing to defaecate and walking at least a few paces thereafter was the predominant behaviour pattern for cows at grass, as Aland *et al.* (2002) noted, and that pre-defaecation behaviours were consistently interrupted to maintain this pattern. For example, on all of a total of 204 occasions, lying behaviour was interrupted with cows standing up to defaecate. Indeed, eliminative behaviour upon rising was expressed significantly more often than voiding prior to lying down. In all management systems, cows tend to defaecate after a long period of lying (Aland *et al.*, 2002; Hörning and Krämer, 2003). This would suggest that there was little reluctance to intersperse or interrupt lying bouts to rise and eliminate. The significantly greater expression of rising to defaecate, as opposed to voiding before lying down, may also have an adaptive component in terms of faeces avoidance and, consequently avoidance of disease. Bacterial and viral diseases, as well as parasites, are associated with faeces on pasture (Michel, 1955; Hart, 1990; Henderson, 1990; Daniels *et al.*, 2001). Broom *et al.*, (1975) noted that animals lie in the area that they have just grazed and lying down without first voiding would ensure an unsoiled lying space. Eliminating upon rising, however, would then ensure that, as the cows moved to a new grazing area, they would not be confronted with grass contaminated with fresh faeces. The dairy cow's aversion to grazing near faeces has been well documented (e.g., Marten and Donker, 1964a; Pain *et al.*, 1974; Hutchings *et al.*, 2002). The grouping of faeces as a result of a concentration of cattle in space and time (Kilgour and Albright, 1971; White *et al.*, 2001) may not be a random consequence of camping behaviour but may, instead, be an alternative stable strategy to latrine behaviour as a way of avoiding parasites and disease.

Of the 205 recorded incidences of rising to void, cows resumed their lying behaviour on only 15 occasions, indicating that although the need to void was the initial trigger for standing up, cows utilised this standing up to perform other activities such as grazing, drinking, etc. Lying down and rising behaviours are the most expensive movements in terms of energy expended and risk of injury (Fuller, 1928; Haley *et al.*, 2001; Jensen *et al.*, 2005) and animals allocate their time between daily activities so that the resulting cost is minimised (Houston and McFarland, 1980). However, only a portion of the cows' day could be observed and different times of the day may have revealed other frequencies of sequence expression. For example, dairy cows perform several grazing bouts during daylight hours but spend most of the night resting and ruminating (Phillips and Denne, 1988), suggesting that resuming lying behaviour post elimination would be more frequent at night.

The recording of activities, as well as walking, standing and lying behaviour, around the time of elimination allowed an insight into why cows were deviating from standing to defaecate and were instead walking. Proportionally 0.47 of cows walked (instead of stood) to eliminate when c) active before and after voiding; 0.36 walked when b) static before and active after; 0.14 when a) active before and static after and 0.05 walked whilst defaecating when d) static both before and after voiding. Within category (c), two activity sequences were included, namely, mfWmf and tdWtd and the motivation to move into a different area of the available pasture or to drink occurred before the elimination event, but why cows then walked or stood to void within the sequence was presumably determined by the level of internal motivation of each cow to achieve their initial goal and subsequently overriding any motivation to stand still to void. Lactating dairy cows can drink in excess of 90 litres of water each day and a high motivation to drink, therefore, is a reasonable explanation for a high level of walking whilst defaecating. It was more surprising that cows appeared equally motivated to move to a different area of pasture when all fields contained the same clover/ryegrass mix, had a similar sward height and topography and when the most obvious effect of milking times on cow movement between fields was avoided. However, cattle tend to alternate among preferred grazing patches more frequently on managed grassland than when kept in more strongly heterogeneous environments (Bailey *et al.*, 1990; Bailey, 1995). Diet selection also changes throughout the day with clover being a preferred food in the morning and grass in the evening (Rutter *et al.*, 2004).

Although statistically more likely to stand to defaecate when b) static before but active after voiding, the largest expression of walking whilst defaecating was also expressed within this category. Two sequences in particular, namely lWcu and lWmf, were expressed on 8 out of 10 occasions. Why cows walked or stood to void after rising must, again, presumably be influenced by the level of motivation of the individual cow to engage in a second activity at the time of voiding. When unrestricted, an animal is likely to express a given behaviour if it is motivated to do so (Kirkden and Pajor, 2006; Lensink *et al.*, 2006). The high motivation to move to a different part of the field is feasibly motivated by hunger whereas the motivation for catch up sequences would be to rejoin the herd. Cows at pasture are highly synchronised in their activities (Castle *et al.*, 1950; Benham, 1982; Arnold, 1984; O'Connell *et al.*, 1989) with behaviours such as lying and grazing considered to be 'contagious' within the herd (Nicol, 1995). In the present study, some cows did continue with a lying bout after the main body of the herd had moved to graze a different part of pasture. Motivation to rejoin the main group may then have been greater for cows lying for longer, resulting in walking whilst defaecating. Lying was, in fact, the pre-defaecation activity in half of all the walking whilst defaecating sequences suggesting that recumbent cows showed some reluctance to rise and as the motivation to engage in a different activity increased, the likelihood of defaecation behaviour occurring whilst walking also increased. Nevertheless, overall, recumbent cows still stood to defaecate significantly more often indicating a preference for maintaining the open-legged, arched-back posture to defaecate (Aland *et al.*, 2002), thereby avoiding soiling their hindquarters and avoiding splashing before initiating a different activity.

Standing to void then walking forward was the predominant behaviour pattern for all cows at pasture, suggesting that cows were aware of their excreta and were averse to remaining in close proximity to it. This is, perhaps, unsurprising when their high sensitivity to faeces and its volatile components during grazing is considered (Dohi et al., 1991; 1999; Aoyama et al., 1994). Avoidance of faeces was maintained by all of the cows in all recorded instances providing evidence of an inherent avoidance of faeces at pasture. This then indicates that the expression of avoidance of excreta by cows at pasture was not inhibited by the environment itself, in contrast to cows housed indoors. It may, however, be influenced by lying eating and drinking patterns and general group activity in the outdoor environment. The majority of elimination events were rated as incidental avoidance because of a lack of a clear and measurable indication of intent, particularly when cows were engaged in different activities before and after voiding. Despite this, the total absence of any expression of 'no avoidance of faeces' and both the very high level of expression of standing to eliminate and moving forward as well as cows' rising in all but one instance to void all strongly indicate that they were aware of what behaviour was required in order to avoid bodily contamination with excreta and that this required behaviour was expressed at the appropriate time for avoidance to occur. This implies a degree of refinement in their response to an elimination event not previously recorded or attributed to cattle (Hafez and Schein, 1962; Brantas, 1968; Kilgour and Albright, 1971; Arave and Albright, 1997).

2.4 Conclusions

Cows at pasture exhibited a range of behaviour sequences around the time of elimination, all of which resulted in avoidance of bodily contamination with excreta. In the majority of incidences, cows stood to eliminate and walked at least a few paces thereafter, providing evidence of a consistent behaviour pattern indicating an inherent avoidance of excreta. Walking whilst defaecating appears to be related to a high motivation to complete an activity which was initiated prior to the defaecation event (e.g., going to drink) or a high motivation to initiate an activity after rising (e.g., catching up with the herd). Lying down upon freshly grazed pasture and eliminating upon rising may be evidence of an alternative stable strategy to latrine behaviour and its role in the control of disease transmission.

Comparisons between cow eliminative behaviour when grazing or housed.

The recording of standing, walking and lying behaviours at the time of voiding support the earlier finding that standing to void, followed by moving forward is the predominant pattern of behaviour in cattle (Aland *et al.*, 2002). There were differences, however, between the most commonly observed sequences for cows at pasture (namely, lSws, sSws and wSws) and for cows housed in either the cubicle system or the straw yard (namely lSs, sSs and wSs), indicating that cows were actively moving away from excreta more often when at pasture than when confined indoors, suggesting that the housing of cows, regardless of housing type, has an effect upon faeces-avoidance behaviour patterns. Differences were also noted in the ratio of lying to standing pre-defaecation behaviour for cows at pasture (1:1) or confined cows (straw 1:4; cubicles 1:4). The greater levels of voiding indoors where the pre-defaecation behaviour was standing, indicate that other daily behavioural patterns including lying and standing were also disrupted compared to cows at pasture (O'Connell *et al.*, 1989; Kondo and Hurnik, 1990).

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