Welfare and health of dairy cattle on out-wintering pads or in cubicle housing with or without cushioned flooring

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Summary and implications

Housing of dairy cows during the winter months is a common component of Irish dairy systems. This facilitates feeding during the winter when grass supply is limited and soils are wet. However, many existing housing systems, particularly those with concrete flooring, can adversely affect the health, welfare, productivity and reproductive performance of the modern dairy cow. Recent attempts to address these problems have focused on modification of aspects of cubicle design and flooring in existing systems as well as through evaluation of alternative bedding materials. More recently attention was drawn to the potential benefits, especially in terms of lameness, of providing cows with cushioned 'relief areas' for standing in cubicle systems. However, the limited results available to date are conflicting.

With forecast reductions in output prices, there is growing interest amongst producers in the use of low cost accommodation options such as out-wintering pads in order to reduce capital investment per cow and maintain viability in the future. This development could do more than

any modification to conventional housing systems to improve the welfare of dairy cattle as higher space allowances and a more ‘natural’ environment are inherent features of such systems.

The first study described in this report involved housing 66 spring calving heifers in one of three systems during the winter, namely, (i) a conventional cubicle house, (ii) a cubicle house with cushioned flooring covering the slats (slat mats) in the passageway and (iii) on a wood-chip out-wintering pad. Behaviour, health and performance indicators were measured on all animals while pregnant from housing in November 2003 until calving in January 2004. Additionally, data were collected on the first 15 animals to calve in each treatment for the first four weeks of lactation in the spring.

The slat mats resulted in some improvements to hoof health compared to the conventional cubicle house. Furthermore, it increased feeding times although this had no effect on feed intake or performance. The results also indicated that heifers have a preference for standing on cushioned flooring rather than on concrete during late pregnancy.

Both groups indoors differed greatly from the outdoor heifers in several respects. The outdoor animals had healthier feet and were less affected by injuries to the limbs. They also had a more diverse behaviour repertoire and slipped and tripped less. However, their welfare was adversely affected by inclement weather conditions with indications of immunosuppression combined with a reduction in average daily gain being recorded. Furthermore, they were dirtier and spent less time lying down. None of these factors influenced milk yield, quality or composition in early lactation.

Welfare problems associated with the pad were weather and management dependent and hence could be addressed by more frequent cleaning of the pad and/or an increase in space allowance combined with the provision of shelter. Hence, the potential for good welfare in dairy heifers was higher on the pad than indoors in a cubicle system even when slat mats were provided.

In the second study, 62 autumn calving pluriparous dairy cows were housed in September 2004 in a cubicle system with either solid concrete floors or solid concrete floors covered by a rubber mat and cleaned by an automatic scrapper. Behaviour, locomotion and foot lesion scores were recorded from at least 3 weeks prior to calving until at least 16 weeks post-partum. Furthermore, in-depth measures of oestrous behaviour and reproductive performance were recorded.

The cushioned flooring had no effect on sole or white line lesion scores or on dermatitis scores. However, it reduced the rate of wear of the heels in early lactation. Cows on cushioned flooring spent more time standing, but not feeding, at the feed face while cows on concrete stood in the cubicles instead.

It appears that where cows have access to spacious, well-designed cubicles they can use them for standing to get relief for their feet from the concrete. Similar to the previous study this also indicates that cows prefer to stand on cushioned flooring than on bare concrete and emphasises the importance of at least providing cows with mats or mattresses in their cubicles. There were no effects of the cushioned flooring on oestrous behaviour or reproductive performance, which was poor in both treatments. It is suggested that the reasons for this were that the cushioned flooring did not provide sufficient traction for the cows and so they were as reluctant as the cows on concrete to perform mounting behaviour.

Slat mats represent a significant investment for dairy farmers attempting to reduce costs and improve efficiency. In order to justify such an investment the provision of cushioned flooring would need to result in significant improvements in the health, welfare and productivity of the dairy animal. In contrast the benefits of cushioned flooring in the current studies were limited and resulted in no performance improvements. However, small improvements in hoof health

were detected in both studies. Foot lesions cause 90% of lameness in dairy cows and the pain caused by lameness makes it one of the most serious of all farm animal welfare issues. Furthermore, the economic implications of lameness are considerable and include reduced milk yield, poorer fertility, higher replacements rates and veterinary charges. Hence, even small improvements in hoof health are of critical importance.

The current studies each focused on one winter housing period but it is reasonable to assume that real improvements in hoof health and ultimately in cow longevity might be achieved if cows had access to cushioned flooring for the duration of their productive lives. There is indisputable evidence from the current studies and the literature that cows prefer to walk and stand on cushioned flooring rather than on solid or slatted concrete. If real improvements are to be made in the welfare of dairy cows we have to start taking their preferences into account when designing housing or management systems.

Finally, it is worth mentioning that the cubicles used in both of the studies were well designed, spacious, bedded with mats or mattresses and that all animals were able to lie simultaneously. Hence, the animals were not reluctant/prevented from using the cubicles for lying and in the absence of cushioned flooring could use them for standing and still get relief for their feet from the floor. On commercial farms, some of the above factors can be limiting. It is possible that in such cases cushioned flooring could offer significant improvements to dairy cow welfare.

Irish research demonstrated proven management programmes that can achieve a farm net profit of €40,000 per annum in 2010 at just below 100 cows (Dillon *et al.,* 2003). However, the reality today is that the average herd size in Ireland is 42 cows. Consequently, for those choosing to remain in milk production the future will require expansion and efficiency, incorporating tight cost control, particularly capital investment per cow. Recent innovations involving out-wintering pads, earth bank tanks and integrated constructed wetland have shown huge potential as low-capital-cost housing and effluent management facilities for dairy cows. In order to be sustainable in the future the environmental and animal welfare constraints associated with such systems must be acknowledged.

In the current study the potential for high animal welfare standards was higher on the out-wintering pad but dairy heifers in this system were subjected to stress, though transient, during periods of strong winds and heavy rainfall. This had negative implications for performance and health. This problem could be overcome by the provision of shelter, an option that is currently under investigation in a large-scale farm trial at Moorepark Ballydague Farm. The dirtiness of heifers on the pad gives rise for concern although it did not affect milk quality. Research at Grange found that the dirtiness of beef cattle accommodated outdoors was greatly affected by stocking density. Therefore, further research is needed to determine the optimum stocking density and frequency of cleaning the pad necessary for dairy cattle particularly if they are to be accommodated on the pad for part of their lactation.

Introduction

Housing of dairy cows during the winter months is a common component of Irish dairy systems. This facilitates feeding during the winter when grass supply is limited and the ground is wet. However, many housing systems, particularly those with concrete flooring, adversely affect the health (Dumelow and Albutt, 1990; Enevoldsen et al., 1994; Webster, 2002a,b), welfare (Hughes and Duncan, 1989; Singh et al., 1993a,b; Nielsen, 1999) and therefore productivity (Kossibaiti and Esslemont, 1997) of the modern dairy cow.

Lameness is one of the most important health and welfare issues for dairy cows and it has significant economic implications for the Irish dairy industry. The aetiology of lameness is multifactorial. However, prolonged standing on concrete when cows are housed over the

winter is a major predisposing factor (Wierenga, 1990; Singh et al., 1993a). Bouckaert (1964) suggested that this is because circulation in the foot is disturbed. Furthermore, falling on slippery concrete floors is responsible for most upper leg lameness (Philipot et al., 1994). While other predisposing factors such as genetics or nutrition are more difficult to address, problems associated with flooring can be rectified more easily. Vermunt and Greenough (1994) recommend that cows being kept on hard surfaces for long periods of time should be given access to areas covered with a softer footing surface to relieve their feet and help reduce the prevalence and incidence of lameness. Indeed, simply providing cows with mats in the cubicles goes some way towards reducing cases of foot lesions (Leonard et al., 1994). Providing rubber flooring in the feed alleys of new freestall barns, or retro-fitting it in existing barns, is becoming common practice in North America. However, research data to support its benefits are lacking and often contradictory. For example, Jungbluth et al. (2003) found that sole bruises in dairy cows were less severe on rubber floors compared to concrete. However, Vokey et al. (2001) found no differences in the severity of sole lesions or incidence of clinical lameness between cattle housed with access to rubber or concrete alleyways over a 16-week period. Nevertheless, differences in days in milk and parity between treatments in the latter study make these results difficult to interpret.

As cattle are able to distinguish between walking surfaces that differ in traction (Phillips and Morris, 2002) it is likely that the flooring surface can modify their behaviour. Indeed, several authors have shown that the gait of dairy cows is affected by floor surface, with softer and more slip resistant flooring reducing various measures of gait abnormality (Vokey et al., 2001; Benz et al., 2002; Flower et al., 2003; Jungbluth et al., 2003). Indeed, softness is one of the most important properties of a floor for dairy cows (Irps, 1983). Telezhenko et al. (2004) showed that cows prefer to walk and stand on soft flooring than on concrete. Nevertheless, Fregonesi et al. (2004) found no effect on time eating of providing rubber flooring in front of the feed face. However, they found small differences in where and how much time cows with rubber flooring in front of the feed face spent standing, although they were not clear as to the biological implications of these changes.

Oestrous detection plays a major role in the reproductive success of dairy cattle (Diskin and Sreenan, 2000). However, oestrous detection rates are decreasing (Washburn et al., 2002) with the efficiency of oestrous detection often being less than 50% (Senger, 1994). One of the reasons for this is that the physiological intensity and duration of oestrous is decreasing (Dransfield et al., 1998). Comparison of oestrus events in Irish dairy cows over the last two decades has shown a reduction in the intensity of oestrus (Mee, 2004). Furthermore, there are concerns that housing on concrete is also responsible for reducing displays of oestrous. Indeed, Britt et al. (1986) found that mounting and standing activity as well as duration of oestrus was reduced on concrete compared to dirt floors. Probably because the under-foot conditions provided by the dirt floor allowed animals more security to stand while being mounted and while mounting. Furthermore, De Silva et al. (1981) showed that mounting activity is reduced in cubicle housing compared to at pasture. Larkin et al. (2003) provided evidence that duration of oestrus and number of mounts were similar on rubber-covered slats, pasture and straw and significantly improved compared to concrete slats. Of course, the occurrence of hoof lesions and lameness and the stress associated with close confinement and slippery under-foot conditions may also combine to affect oestrous expression.

One of the effects of the forecasted reduction in the allocation of EU subsidies is that producers will be forced to reduce capital investment per cow to remain competitive in the future. So while cubicle houses continue to represent the most popular housing system for dairy cows in this country there is growing interest in the use of low cost housing options. Out-wintering cattle on out-wintering, wood-chip pads is an option with great potential for use in this country. These pads originated in New Zealand where they are commonly used to ‘stand cows off’ during periodic weather-induced removal from pasture (see Fisher et al.,

2003). Most of the previous work on out-wintering pads was conducted at Grange research centre with beef cattle (e.g. Hickey et al., 2002). These authors found that the animals accommodated outdoors had higher daily live and carcass weight gain and food intake. They also had leaner carcasses and consumed less energy per kg carcass growth. No behaviours indicative of distress in animals accommodated on out-wintering pads relative to animals housed on slats were found and there was no difference in lying time between animals accommodated on out-wintering pads relative to their counterparts on slats. Heel erosion was more severe on the hind feet of out-wintered animals compared to animals indoors on slats. Hickey et al. (2002) attributed this to standing for long periods in wet, corrosive slurry which would not have been a problem if the animals fed off the pad. There is convincing evidence that the incidence of claw lesions is greater for cows housed in cubicles than in straw yards (Livesey et al., 1998; Webster, 2001). This difference may be attributed in part to the physical surface (Bergsten and Frank, 1996) and in part to the fact that cows in straw yards spend more time lying down (Singh et al., 1993b).Hence, it could be expected that foot lesions would be less of a problem for cows kept on an out-wintering pad than for cows indoors on concrete.

The aims of the first experiment described in this report were to evaluate out-wintering pads as an out-wintering system for primiparous heifers and to assess the effect of providing such animals with cushioned flooring in a cubicle housing system. Systemic changes in heifers at calving are one of the triggering factors for claw horn lesions, setting in motion a chain of events that are influenced by environmental and dietary factors (Livesey et al., 1998; Webster, 2001). It was expected that the environmental factors inherent to the systems under investigation in this experiment would have a favourable influence primarily on claw horn lesions. Behavioural, production and physiological parameters were also used as welfare indicators.

The second part of this project evaluated the effect of providing autumn-calving pluriparous dairy cows with cushioned flooring in the passageways. These animals have even poorer reproductive performance than their spring-calving counterparts and it was expected that the rubber flooring would increase the duration of standing oestrus and mounting behaviour. Furthermore, improvements in foot lesions were expected.

Effect of cushioned flooring in cubicle housing and out-wintering on an out-wintering pad on the behaviour and welfare of dairy heifers

Materials and methods

Animals and housing

Sixty-six, in-calf, spring-calving Holstein-Friesian heifers blocked on liveweight and expected calving date were assigned to three housing treatments in October 2002. The treatments were: CONTROL - Cubicles bedded with rubber mats with concrete slatted flooring in the passageway and solid concrete flooring at the feed face; MODIFIED - Cubicles bedded with rubber mats with additional cushioned flooring (RJM Anti-Lameness Mat, R.J.M. Mooney, & Son Ltd., Avonbeg Industrial Est., Dublin 12, Ireland) on the slatted flooring in the passageway and in a 0.5m strip at the feed face (the latter was in place for only the first month of the experiment as it was damaged by the automatic scrapper) and OUTDOOR - Out-wintering, wood-chip pad with a separate concrete feeding area. Heifers were removed from their respective treatments to a straw-bedded calving pen approximately 24-48 hours before calving until the first milking. The first 15 heifers to calve in each group were returned to their respective treatments for the first four weeks of lactation.

Cubicle house showing passageway covered with slat mats (MODIFIED treatment)

Wood-chip out-wintering pad (OUTDOOR treatment)

Concrete feeding area (OUTDOOR treatment)

Close-up of slat mats (RJM Anti-Lameness Mat®)

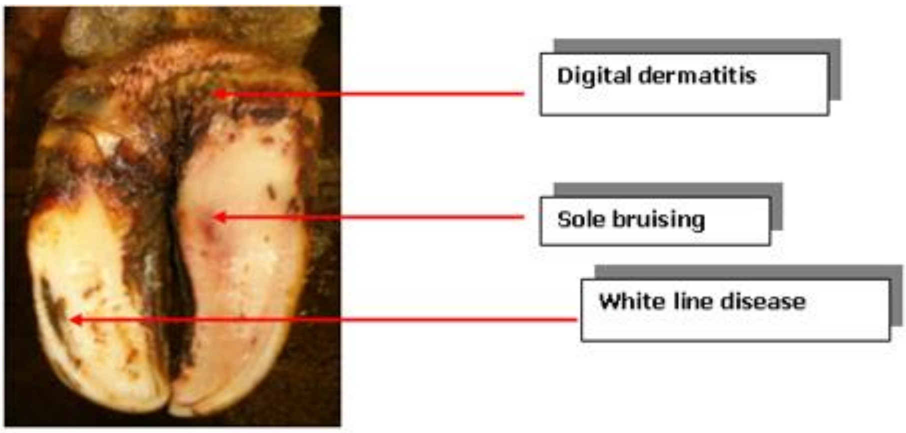
Limb lesions

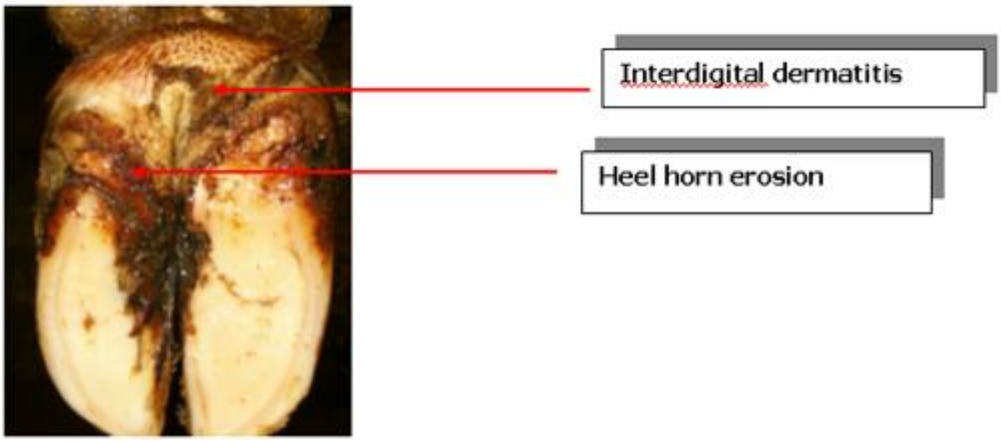
Ten areas on the limbs (including: the humerus, knee, lateral aspect of the knee, front fetlock, flank, hip, hock, hock lateral, 'inside' hock and hind fetlock) were inspected for skin lesions which were scored from 0 to 6 according to severity. Animals were scored on a fortnightly basis during pregnancy and on each of the four weeks after calving. The overall severity of the lesions was described by a cumulative score, which defined the product of the severity of the lesions in each animal.

Foot lesion scoring

The hind feet of each animal were examined 0, 4, 8 and 12 weeks, relative to the start of the experiment and 1, 4 and 8 weeks after calving. All four claws were cleaned and lightly trimmed in a restraining chute. A sliver of horn was pared from the whole area of the weight-bearing surface to expose fresh horn. Haemorrhages were localised as to zone of the sole (6 regions as per Greenough and Vermunt, 1991). The severity of haemorrhages observed in each zone were scored on a 4 point scale (as per Greenough and Vermunt, 1991). The scores for the 6 zones of all four claws were then added to give a sole and white line lesion score for each animal at each inspection. The presence of interdigital and digital dermatitis was determined by gross examination of the plantar area of the interdigital skin and the bulb area of the hind feet. The severity of dermatitis lesions was then rated on a four-point scale. Evaluation of the severity of heel horn erosion was according to a four-point scoring system described by Peterse (1980). The three individual scores were also added together to give a total foot lesion score for each animal.

Lesions affecting the right hind feet of two heifers





Dirtiness scores

Five areas of the animal (body, front limb, hind limb, hind quarter and udder) were scored including half points for dirtiness using a scoring system described by Bergsten and Pettersson (1992). Animals were scored on a fortnightly basis throughout pregnancy and on each of the four weeks after calving. The sum of the four scores constituted the total dirtiness score.

Behaviour

Behaviour was monitored by instantaneous scan sampling (Martin and Bateson, 1993) whereby the activity (ruminating, feeding, idling, sleeping, active), posture (standing, lying or standing half [indoor treatments only]) and location (lying area or feed face) of each animal was recorded every 15mins. These observations were conducted once per week over 24hours at approximately three-week intervals starting 10 days after the heifers entered the housing treatments until the first heifer calved (four observations). In the intervening weeks observations were conducted over a 12hr (0800-2000h) period one day per week (four observations). The first 15 heifers to calve in each treatment were also observed for 12hours (0900-2100h) per week during each of the first four weeks of lactation.

Haematology

Blood samples were collected via tail head venepuncture prior to housing and thereafter on a fortnightly basis during pregnancy and on weeks 1 and 4 of lactation. One blood

sample/animal was collected into a vacutainer containing K3 EDTA (Becton and Dickinson Vacutainer, Unitech, Tallagh, Co. Dublin) for the assessment of haematological profiles. Blood samples were transported to the Irish Equine Centre (Johnstown, Ireland) on the day of collection where haematological profiles were determined using an Abbott Cell Dyn 3500. Blood samples were analysed for white blood cell counts, neutrophil percentage, lymphocyte percentage, monocyte percentage and eosinophil percentage.

Interferon-γ (IFN-γ) production

Two heparanised blood samples were collected via the jugular vein from 10 randomly selected pregnant heifers from each treatment six (December 2002) and ten weeks (January 2003) after the start of the experiment. Interferon-γ (IFN-γ) production in response to mitogens Concanavalin A (ConA) and Phytohaemagluttinin (PHA) were quantified in vitro using an enzyme immunoassay (Bovigam, Biocor Animal Health, Inc.) at Grange Research Centre. Duplicate 1.48 -ml aliquots of blood were cultured in 24-well culture plates (Costar Corporation, Cambridge, MA) with 20 µl of phosphate-buffered saline (PBS) containing either 1.0 mg/ml of Con-A or 1.0 mg/ml of PHA or no additive, for 16h at 37 ^{o}C and in an atmosphere of 5 % CO2 in air. The culture plates were then centrifuged and the supernatant harvested and frozen at –20 oC until it was assayed for γ-interferon production using an ELISA procedure (BOVIGAM, Biocor Animal Health). The in vitro PHA and Con-A stimulated γ-interferon production was then calculated by subtracting the absorbency at 450 nm of wells that received PBS alone from the absorbency of wells that received either Con-A or PHA, respectively.

Production/performance

All heifers were weighed unfasted on two occasions prior to entering the housing treatments and fortnightly thereafter during pregnancy and on each of the four weeks postpartum. Average daily gain (ADG) was calculated from the difference between the means of initial and final weights divided by the number of days the animals were on experiment. The daily milk yield of the first 15 animals to calve on each treatment was recorded immediately post-calving for the first 8 weeks of lactation. Milk yields were recorded using electronic milk meters (Milkscan). In addition, milk composition (concentrations of fat, protein and lactose) and somatic cell counts were determined in one successive morning and evening sample of milk per week.

Statistics

All data were analysed by SAS. Total foot lesion scores, body weights during lactation, haematological parameters, milk yield and quality were analysed using the MIXED procedure. The pre-housing values for total foot lesion scores were used as a covariate in the analysis. Sole and white line, dermatitis, heel erosion, limb skin lesion and dirtiness scores were analysed using the non-parametric 1-way ANOVA procedure. Data on average daily gains were analysed by analysis of variance using the GLM procedure.

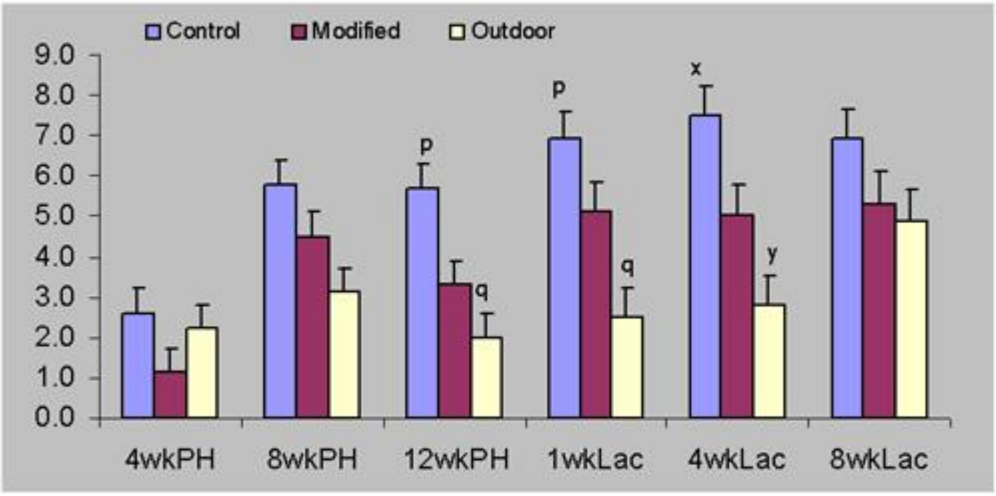
Results

Foot lesion scores

There was a significant time by treatment effect on foot lesion scores ($P<0.001$) (Figure 1). OUTDOOR heifers had lower total foot lesion scores than CONTROL heifers 12 weeks after housing as well in the first and fourth week of lactation. Foot lesion scores of MODIFIED heifers were intermediate and never differed significantly from the OUTDOOR animals.

However, they tended to be lower than those of the CONTROL heifers one and four weeks post-partum (P<0.10).

Figure 1. Effect of treatment on total foot lesion scores (lsmean ±s.e.) of heifers at six inspections



Superscripts [pq] P<0.01 and [xy] P<0.001
4wkPH=4 weeks post-housing; 8wkPH=8 weeks post-housing; 12wkPH=12 weeks post-housing; 1wkLac=Week 1 of lactation; 4wkLac=Week 4 of lactation and 8wkLac=Week 8 of lactation.

OUTDOOR heifers had significantly higher sole and white line lesion scores than heifers in either of the indoor treatments four (P<0.05) and eight (P<0.001) weeks post-housing (Table 1). They also had significantly higher scores than the CONTROL heifers in weeks four and eight of lactation (P<0.05) and tended to have higher scores than the MODIFIED heifers in week four of lactation (P<0.10). CONTROL heifers had higher dermatitis scores than OUTDOOR heifers at weeks one (P<0.01) and four (P<0.001) of lactation. MODIFIED heifers tended to have higher scores than the OUTDOOR heifers in the first week of lactation (P<0.10) and had significantly higher scores in week four of lactation (P<0.05). OUTDOOR heifers had significantly lower heel erosion scores than either group of indoor heifers eight (P<0.001) and 12 weeks (P<0.01) post-housing and at all inspections during lactation (P<0.01). MODIFIED heifers tended to have lower heel erosion scores than CONTROL heifers (P<0.10) 12 weeks post-housing.

Table 1. Sole and white line (WL) lesion, dermatitis and heel erosion scores (mean ±s.e.) of heifers in three treatments at six inspections

Week	Control			Modified			Outdoor		
	Sole/WL lesion	Dermatitis	Heel erosion	Sole/WL lesion	Dermatitis	Heel erosion	Sole/WL lesion	Dermatitis	Heel erosion
4P	0.1 ±	0.7 ±	**1.7 ±**	0.1 ±	0.3 ±	**1.0 ±**	0.4 ±	0.6 ±	**0.9 ±**

Table 1. Sole and white line (WL) lesion, dermatitis and heel erosion scores (mean ±s.e.) of heifers in three treatments at six inspections

Week	Control			Modified			Outdoor		
	Sole/ WL lesion	Dermatitis	Heel erosion	Sole/ WL lesion	Dermatitis	Heel erosion	Sole/ WL lesion	Dermatitis	Heel erosion
H	0.09 a	0.17	**0.44**	0.09 a	0.12	**0.27**	0.16 b	0.16	**0.27**
8PH	0.1 ± 0.05 x	0.9 ± 0.23	**4.7 ± 0.62x**	0.1 ± 0.05 x	0.6 ± 0.17	**4.2 ± 0.62 x**	1.0 ± 0.33 y	0.7 ± 0.17	**1.1 ± 0.29 y**
12PH	0.1 ± 0.08	1.1 ± 0.25	**4.4 ± 0.68 x**	0.1 ± 0.08	0.7 ± 0.14	**2.7 ± 0.57 p**	0.3± 0.19	0.6 ± 0.17	**0.7 ± 0.27 qy**
1Lac	0.3 ± 0.13	1.5 ± 0.24 p	**5.7 ± 0.71 x**	0.7 ± 0.24	0.9 ± 0.22	**4.2 ± 0.66 x**	1.4 ± 0.65	0.4 ± 0.19 q	**0.6 ± 0.34 y**
4Lac	0.3 ± 0.19 a	1.8 ± 0.31 x	**5.8 ± 0.79 x**	0.3 ± 0.19	1.1 ± 0.29 a	**4.8 ± 0.74 x**	1.7 ± 0.56 b	0.3 ± 0.16 b,y	**0.7 ± 0.36 y**
8Lac	0.1 ± 0.14 a	1.4 ± 0.27	**5.9 ± 0.68 x**	0.4 ± 0.31	1.1 ± 0.26	**4.8 ± 0.81 p**	2.7 ± 1.15 b	0.8 ± 0.32	**1.5 ± 0.62 qy**

4PH=4 weeks post-housing; 8PH=8 weeks post-housing; 12PH=12 weeks post-housing; 1Lac=Week 1 of lactation; 4Lac=Week 4 of lactation and 8Lac=Week 8 of lactation. Superscripts ^{ab} P<0.05; ^{pq} P<0.01; ^{xy} P<0.001

Limb lesion scores

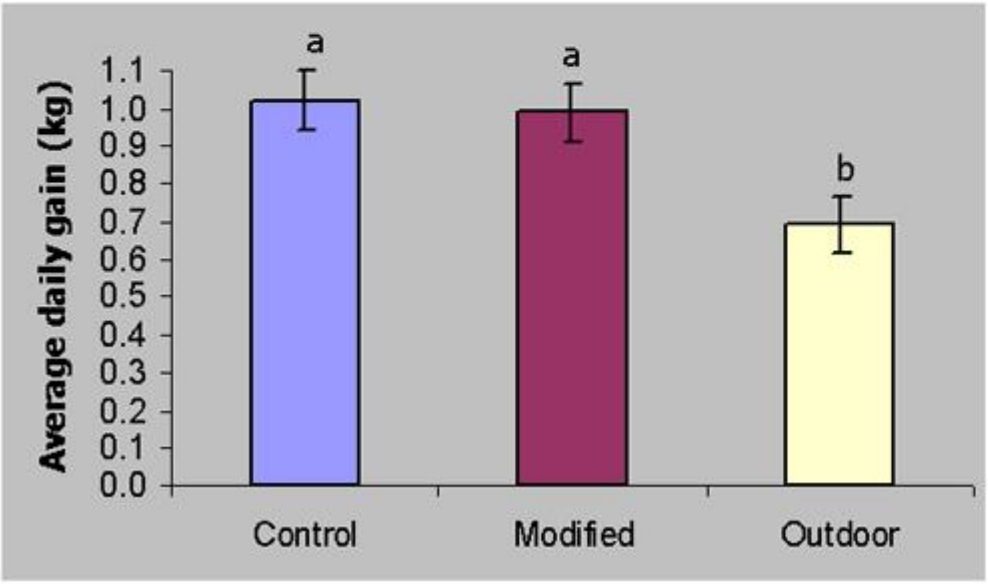
There tended to be a difference in limb lesion scores between treatments two and four weeks post-housing (Table 2). Both indoor groups had significantly higher scores than OUTDOOR heifers 4, 6, 8 and 10 weeks after housing and on each of the first four weeks of lactation. Lesion scores of all heifers increased during the experiment, being highest towards the end of pregnancy and decreasing during early lactation.

Table 2. Limb lesion scores (mean ±s.e.) of heifers in three treatments during pregnancy and early lactation				
Inspection	**Control**	**Modified**	**Outdoor**	**P**
2wk post-housing	0.5 ±0. 34	1.2 ± 0.47	0.2 ± 0.18	=0.076
4wk post-housing	1.3 ± 0.34	1.4 ± 0.51	0.4 ± 0.29	=0.052
6wk post-housing	3.7 ± 1.25	3.3 ± 1.19	0.9 ± 0.73	<0.05
8wk post-housing	5.4 ± 1.49	5.7 ± 1.44	1.6 ± 0.84	<0.01
10wk post-housing	9.7 ± 1.36	8.4 ± 1.65	3.9 ± 1.12	<0.01
1st week of lactation	2.4 ± 0.65	3.7 ± 0.79	0.3 ± 0.27	<0.001
2nd week of lactation	3.4 ± 0.80	4.0 ± 0.99	0.5 ± 0.40	<0.001
3rd week of lactation	3.9 ± 0.96	4.2 ± 0.69	0.6 ± 0.40	<0.001
4th week of lactation	5.7 ± 0.86	5.4 ± 1.00	0.5 ± 0.27	<0.001

Daily weight gain during pregnancy and body weights during lactation

OUTDOOR heifers had lower average daily gains during pregnancy than both groups of heifers indoors (P<0.05) (Figure 2).

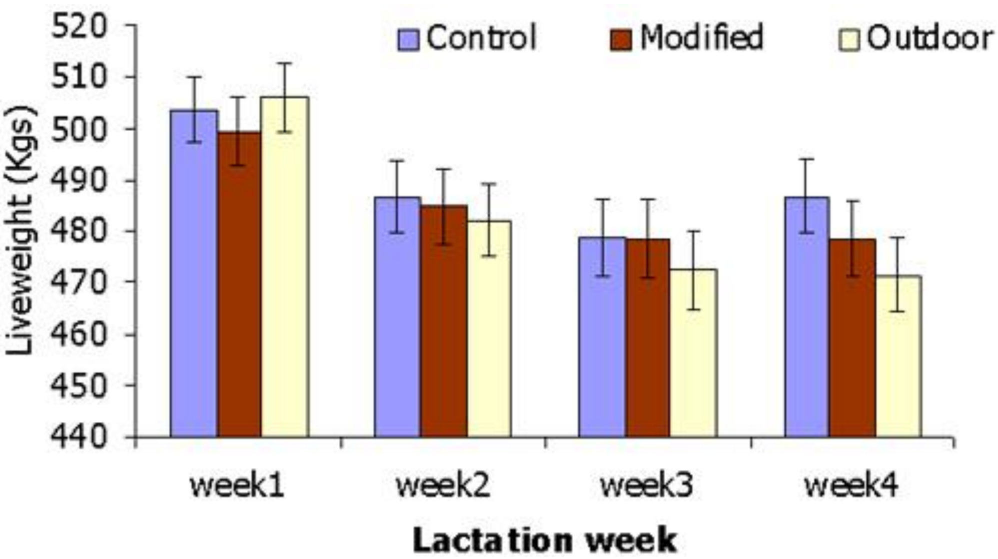
Figure 2. Effect of treatment on average daily gain (lsmean ±s.e. kg/day) of heifers during pregnancy



Superscripts ^{ab} P<0.05

There was no effect of treatment or time by treatment interaction effect on body weights of heifers during the first four weeks of lactation (P>0.05) (Figure 3). There was a significant effect of time (P<0.001).

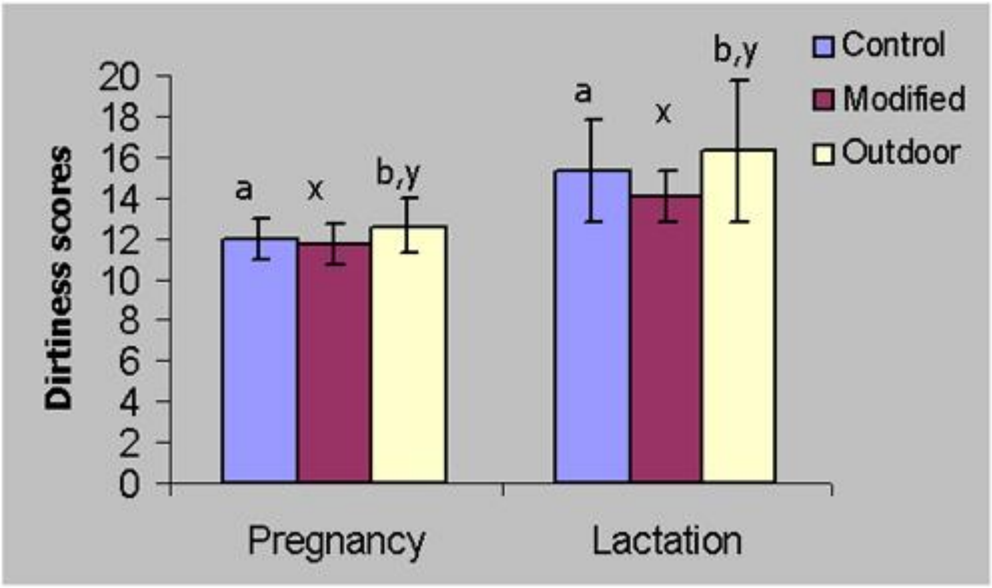
Figure 3. Effect of treatment on body weights (lsmean ±s.e. kg) of 15 heifers per treatment during the first four weeks of lactation



Dirtiness scores

OUTDOOR heifers were significantly dirtier than CONTROL and MODIFIED heifers during pregnancy and in early lactation (P<0.05 and P<0.001 respectively) (Figure 4).

Figure 4. Effect of treatment on dirtiness scores (median ± IQR) of heifers during pregnancy and early lactation

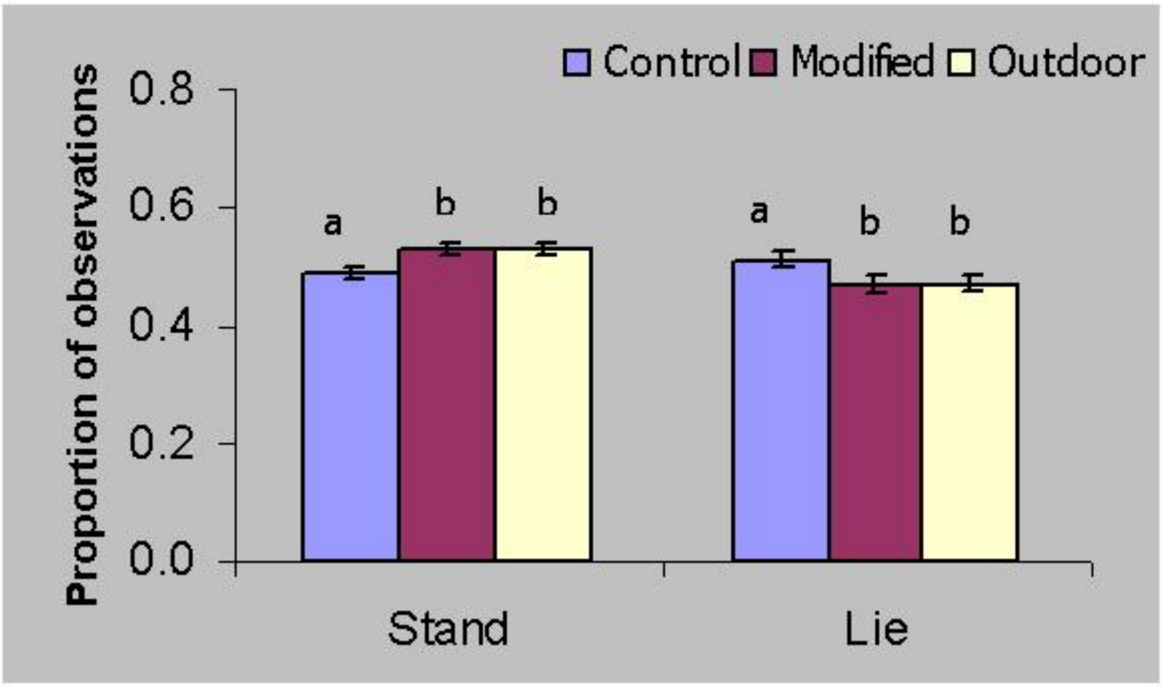


Superscripts ab P<0.05; xy P<0.001

Behaviour

Treatment had a significant effect on standing and lying behaviour during pregnancy (Figure 5). OUTDOOR and MODIFIED heifers stood more and lay less than the CONTROL heifers (P<0.05).

Figure 5. Effect of treatment on standing and lying behaviour (mean ± s.e.) during pregnancy (average of four 24hr observations)

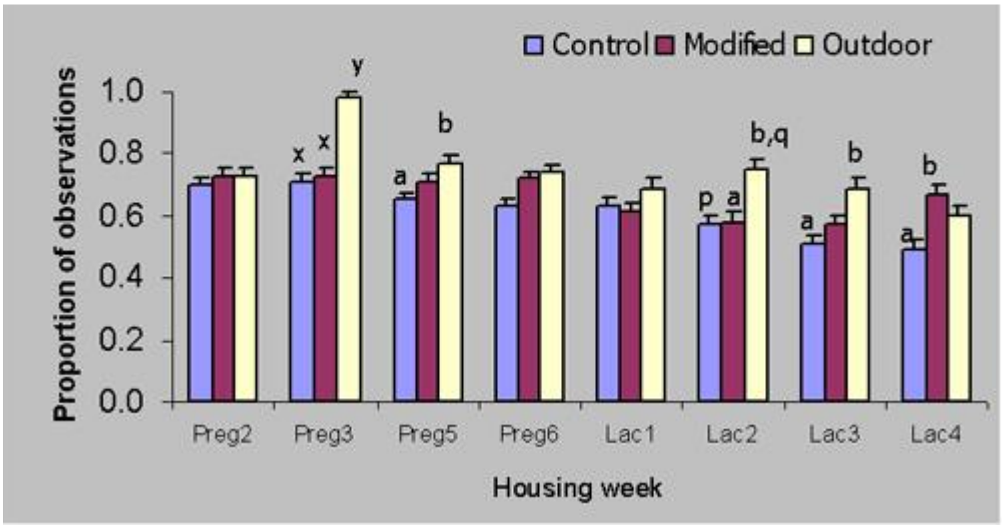


Superscripts ab P<0.05

There was a significant treatment (P<0.001), time (P<0.001) and time x treatment interaction on standing behaviour during the housing period (Figure 6). There was no effect of treatment two or six weeks post-housing or on the first week of lactation (P>0.05). Three weeks after

housing, OUTDOOR heifers stood for significantly longer than either group indoors (P<0.001). They also stood for longer than the CONTROL animals five weeks post-housing (P<0.05). During the second week of lactation OUTDOOR animals stood more than the CONTROL (P<0.01) and MODIFIED (P<0.05) heifers. On week four of lactation, MODIFIED heifers stood for longer than CONTROL heifers (P<0.05).

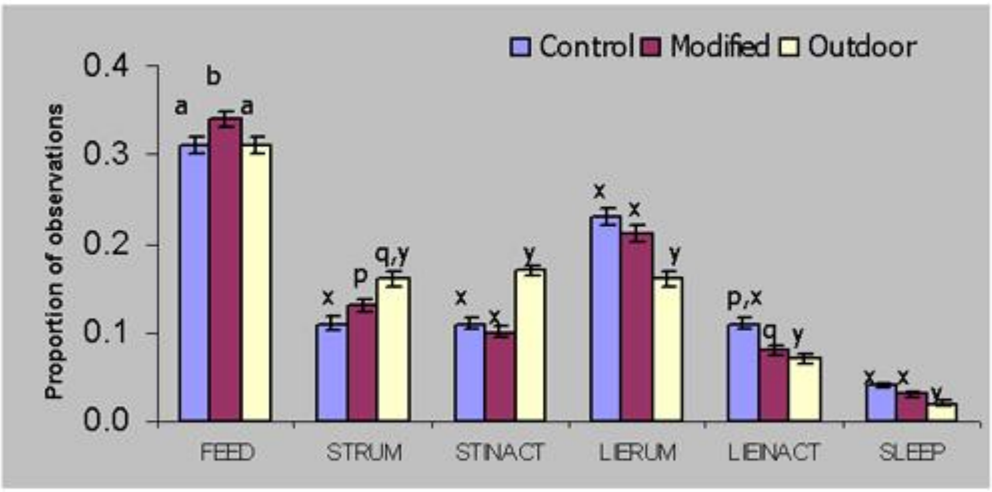
Figure 6. Effect of treatment on standing behaviour (mean ± s.e.) on four 12-hour observations during pregnancy and four 12-hour observations on each of the first four weeks of lactation



Superscripts [ab] P<0.05; [pq] P<0.01; [xy] P<0.001

Treatment also had a significant effect on behaviours performed while standing and lying (Figure 7). MODIFIED heifers spent longer feeding than CONTROL or OUTDOOR heifers (P<0.05). OUTDOOR heifers spent longer ruminating while standing and less time ruminating while lying than either group indoors (P<0.01). They also spent more time standing inactive than either group of indoor heifers (P<0.001). Both MODIFIED and OUTDOOR heifers spent less time lying inactive than CONTROL heifers (P<0.01 and P<0.001 respectively). OUTDOOR heifers also slept less than either group indoors (P<0.001).

Figure 7. Effect of treatment on behaviours performed while standing and lying (median ± IQR)

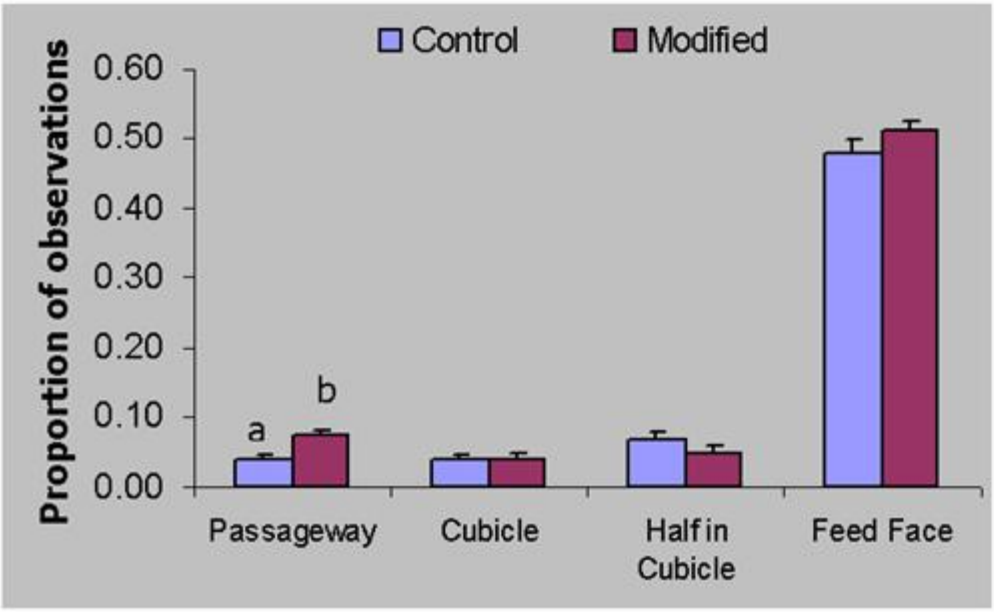


Superscripts ab P<0.05; pq P<0.01; xy P<0.001

STRUM=stand ruminate; STINACT=stand inactive; LIERUM=lie ruminate; LIEINACT=lie inactive

MODIFIED heifers were observed standing in the passageway between the cubicles in a higher proportion of observations than CONTROL heifers (P<0.05) (Figure 8). The cushioned flooring had no significant effect on standing in the cubicles, standing half-in the cubicles or standing at the feed face.

Figure 8. Effect of indoor housing treatment on location of heifers while standing (mean ± s.e.)



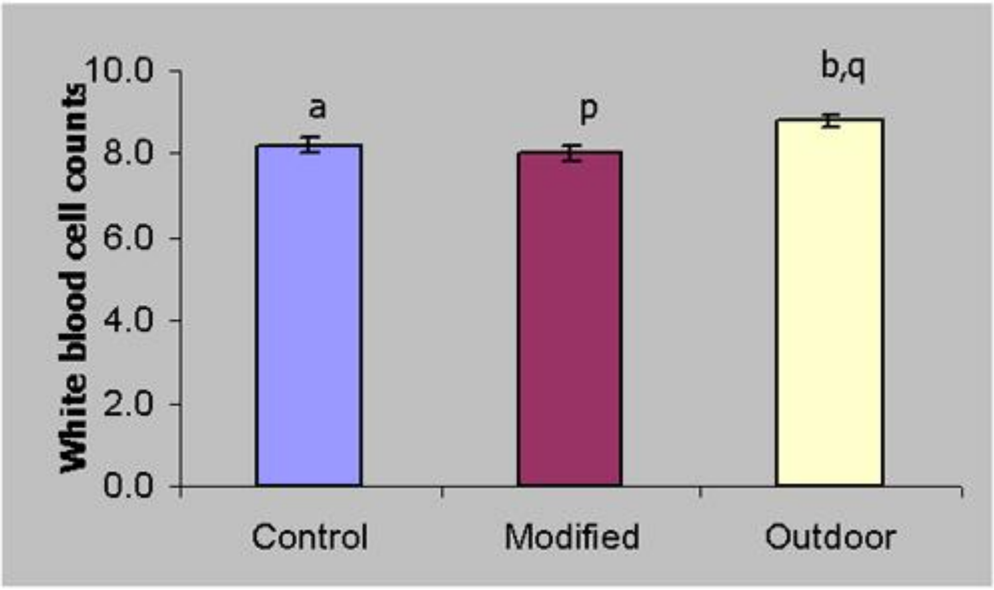
Superscripts ab P<0.05

More incidences of tripping, slipping and colliding with the fixtures and fittings were recorded in both indoor treatments compared to the OUTDOOR treatment (CONTROL=24, MODIFIED=27 versus OUTDOOR=2). In addition, more incidences of play behaviour were observed in the OUTDOOR treatment (CONTROL=11, MODIFIED=14 versus OUTDOOR=35).

Haematology

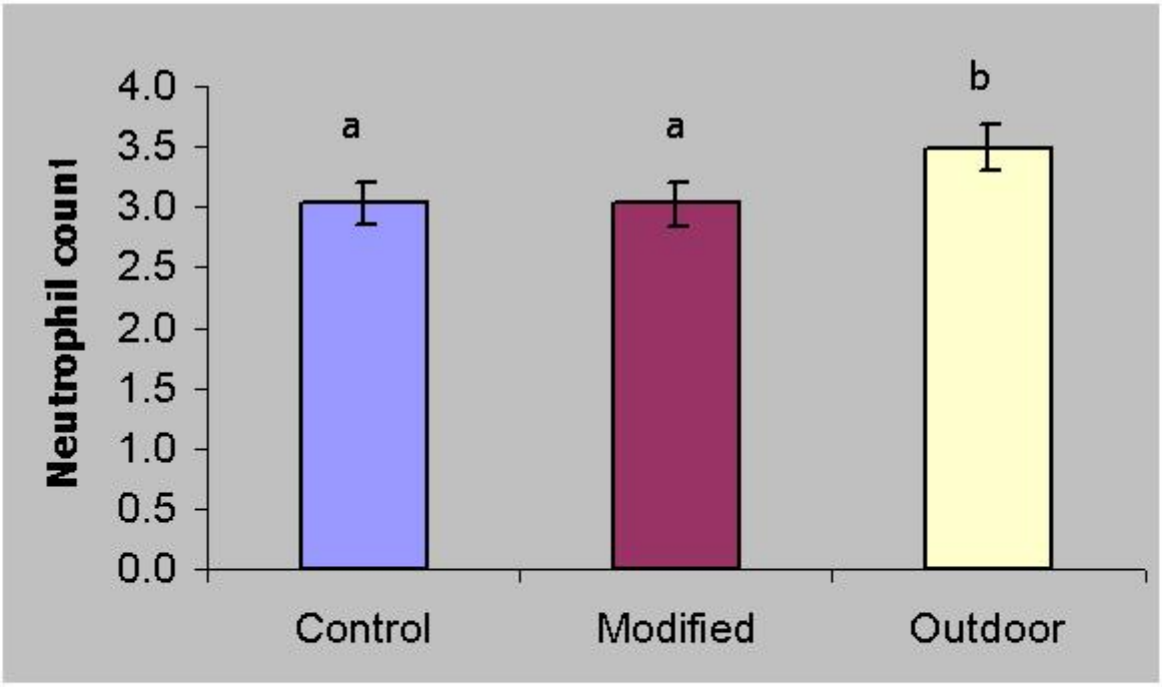
There was a significant effect of treatment on white blood cell counts (P<0.01) but no time by treatment interaction (P>0.05) (Figure 9). OUTDOOR heifers had higher white blood cell counts throughout the experimental period than either group of heifers indoors (P<0.05). There was also a significant effect of treatment on neutrophil counts (P<0.01) but no time by treatment interaction (P>0.05) (Figure 10). OUTDOOR heifers had significantly higher counts than either group of heifers indoors 9P<0.05).

Figure 9. Effect of treatment on white blood cell counts (lsmeans ± s.e.)



Superscripts [ab] P<0.05; [pq] P<0.01

Figure 10. Effect of treatment on neutrophil counts (lsmeans ± s.e.)



Superscripts [ab] P<0.05

In-vitro interferon-gamma production

There was no significant treatment effect on in vitro interferon-gamma production in response to novel challenges with the mitogens Phytohaemagluttinin (Figure 11) and Concanavalin A (Figure 12) (P>0.05). However, interferon gamma production in response to both mitogens was clearly reduced in the OUTDOOR heifers compared to those housed in both indoor treatments on both test days.

Figure 11. Effect of treatment on interferon gamma [INF-γ] production (mean ± s.e. optical density, absorbance @ 450 nm) in response to phytohaemagluttinin [PHA]

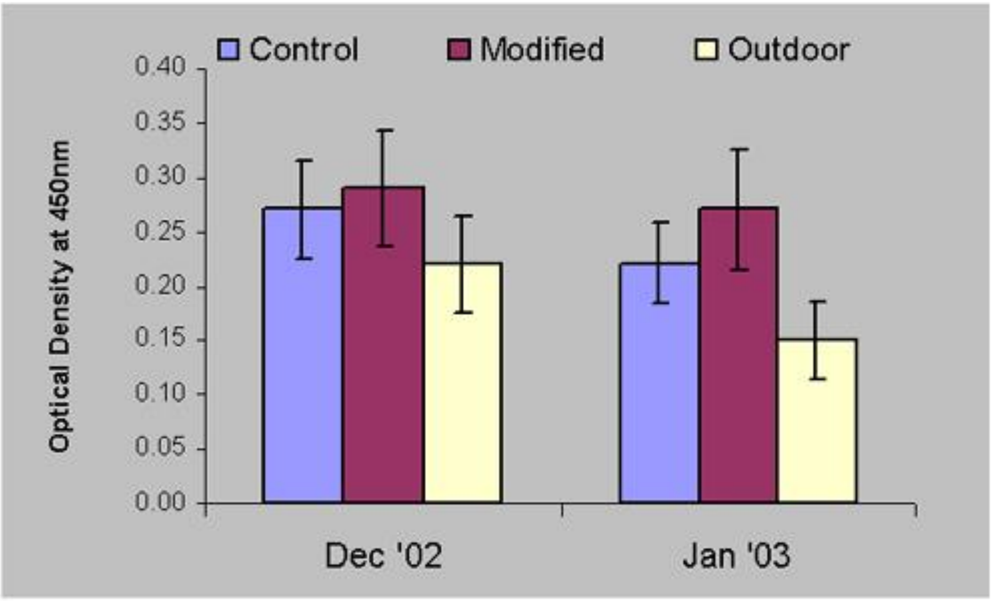
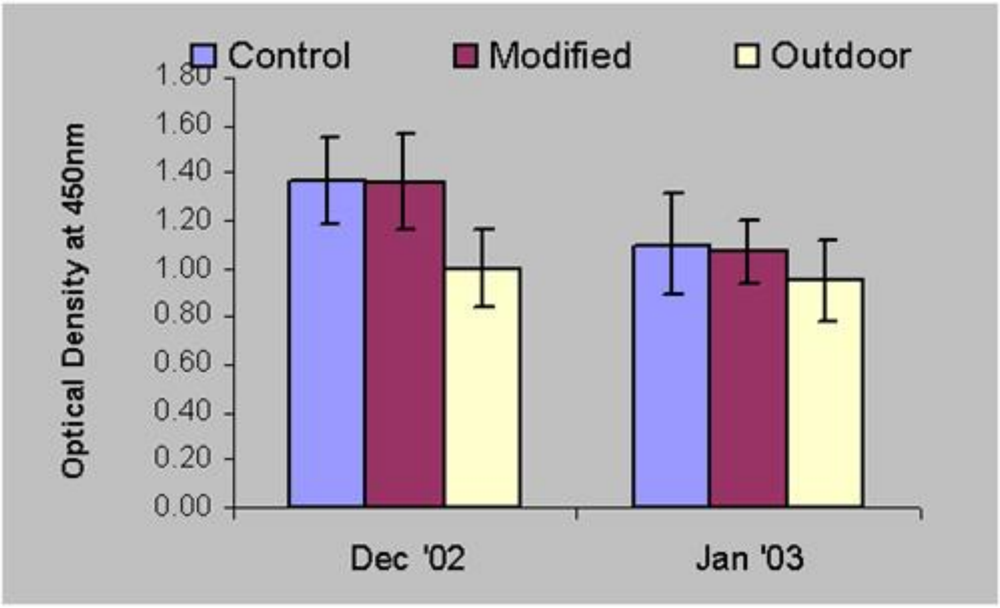


Figure 12. Effect of three housing treatments on interferon gamma [INF-γ] production (mean ± s.e. optical density, absorbance @ 450 nm) in response to Concanavalin A [Con A]



Milk yield, composition and somatic cell counts

There was no effect of treatment on milk yields, milk composition or on somatic cell counts (P>0.05, data not shown).

Discussion

Foot health

There was evidence that providing heifers indoors with relief from the concrete floor during pregnancy improved total foot lesion scores in the early post-partum period (e.g. Webster, 2002a, Laven and Livesey, 2004). This was mostly because the mats protected the feet from heel erosion which agrees with the findings of the second paper in this report. However, they did not reduce bruising relative to the control treatment which is in contrast to a study by Jungbluth et al. (2003). A narrow strip of rubber flooring was placed at the feed face in the modified treatment at the beginning of the experiment. However, it was removed after one month because the automatic scrapper damaged it. In cubicle houses most of the animal traffic and agonistic interactions take place around this area so it is likely that this is where cushioned flooring is most needed. This could explain the lack of a difference between indoor treatments in sole and white line lesion scores. Nevertheless, even slight improvements in the hoof health of heifers in early lactation is of major importance considering that cows that develop lameness in their first lactation are more likely to become lame in subsequent lactations (Hirst et al., 2002).

The out-wintered animals had the lowest total foot lesion scores throughout the experiment indicating that they had healthier feet in general. This difference between housed and outdoor cattle has been reported in other studies (Clarkson et al, 1996; Cook, 2003). However, they had a greater degree of sole and white line haemorrhages (bruising) than both indoor treatments. Malmo (1991) and Baggott and Russell (1981) suggest that sole haemorrhages may also be associated with excessive wear of the bovine claw. Indeed, Mogensen et al. (1997) found that heifers that had longer standing times on an unbedded area at the feed face showed a higher degree of claw wear. During periods of adverse weather heifers in the current study stood for prolonged periods. Indeed they were never observed to lie down during a 12-hour observation conducted 3 weeks after the start of the experiment when the weather was particularly bad (see Figure 6). It was also noted during this observation that all the heifers stood huddled together on the concrete feed apron rather than on the wood-chip pad. This was probably because the concrete section was less elevated than the pad and thus offered more shelter. Hence it is likely that their claws were more worn which would have pre-disposed them to sole bruises. Indeed, several studies suggest that sole bruising is linked to prolonged standing (e.g. Singh et al., 1993a; Livesey et al., 1998; Galindo and Broom, 2000). However, while outdoor heifers stood more than both groups of animals indoors, they still spent around 50% of their time lying which is within an acceptable range (Blowey, 2005). Mogensen et al. (1997) also found more heel erosion in heifers at lower space allowances which explains the higher severity of heel erosion scores recorded indoors where the animals were more tightly stocked than on the pad. Heel horn erosion is a very common condition in cattle housed in wet, unhygienic environments (Baggott and Russell, 1981; Bergsten and Pettersson, 1992; Muldoon, 1995; Hickey et al., 2002). While the out-wintered animals were dirtier than the animals indoors it is still likely that conditions in the former system were more hygienic. This is further supported by the increased incidence of dermatitis in both control and modified cows, which is a further symptom of unhygienic conditions (Blowey and Sharpe, 1988; Muldoon, 1995).

No cases of clinical lameness were recorded during the first 8 weeks of lactation. However, there were signs of foot lesions in nearly all heifers. Foot lesions are associated with approximately 90 percent of cattle lameness (Murray et al., 1996). Mulling and Lischer (2002) and Webster (2002b) suggest that the primary insult to the structural integrity of the foot, resulting in the development of foot lesions in early lactation, is systemic and due to the hormonal changes associated with the physiological processes of parturition and the onset of lactation. However, Whay et al. (1997) asserts that environmental factors such as housing and nutrition, as well as genetic predisposition to lameness are all likely to interact at this

time of heightened sensitivity to influence the onset and severity of claw lesions. Therefore, cow comfort in the form of soft bedding and suitable walking surfaces are of particular importance in the first weeks of lactation (Mulling and Lischer, 2002). In the present study, the outdoor heifers had to walk a distance of approximately 1/4-mile along a farm roadway to the milking parlour during the first 4 weeks of lactation while the indoor cows were housed within 100 yards of the parlour. This likely explains why their sole and white line lesion scores peaked at the 8-week inspection and why there was a dramatic increase in their total foot lesion scores at this inspection having remained static throughout the housing period. Indeed, Muldoon (1995) reported that bruising of the sole is commonly seen in heifers early in their first lactation and is a regular problem when animals travel over roads or pathways with rough surfaces, particularly when horn is soft after the winter housing period.

Limb lesions

The heifers housed in both indoor treatments had higher limb lesion scores than the heifers housed outdoors. The occurrence of any physical injury is an important indicator of the herd health status and a negative effect of the production environment (Enevoldsen *et al.,* 1994). Indeed, De Vries *et al.* (1986), Wierenga (1987) and Webster (2002a) state that such lesions are painful and constitute a welfare problem. Problems with getting up and lying down owing to poor cubicle design and unsuitable lying surfaces can predispose to lesions to the hock, knees and teats (Mortensen, 1978; Munksgaard and Chaplin, 2000). Nevertheless, the cubicles used in this study were bedded with comfortable mats and were well designed. It is more likely that the higher incidence of slips, trips and collisions in both indoor treatments compared to the out-wintering pad was responsible for the injuries recorded (Mitchell, 1974; Faull et al., 1996). These traumatic contacts with the house fixtures and fittings probably arose due to a combination of the restrictive physical environment, the slippery nature of the concrete flooring at the feed face owing to the action of the automatic scraper, the automatic scraper itself and increased cow traffic indoors. Limb lesion scores peaked in all treatments 10 weeks post-housing. This corresponded to late pregnancy for the majority of animals and indicates that their larger size and increasing awkwardness at this stage made them even more susceptible to injury.

Dirtiness scores

Heifers accommodated on the out-wintering pad were dirtier than heifers indoors during pregnancy and lactation. Similarly, Fregonesi and Leaver (2001) showed that cows accommodated in straw yards become dirtier than cows housed in cubicles. The cleanliness of the animals within a housing system depends on whether or not there are clean areas available for lying (Scott and Kelly, 1989). Cubicles will always provide a cleaner lying area for animals indoors. However, the availability of a clean, dry lying area on a pad or in a straw yard can be influenced by the frequency of cleaning (Fregonesi and Leaver, 2002). In the current study this was performed twice during the housing period. The pad may have needed more frequent cleaning or alternatively a lower stocking density (Hickey et al., 2002). The association between clean housing, clean animals and lower herd bulk tank somatic cell counts has been well documented (Bodoh *et al.,* 1976; Barkema *et al.,* 1998; Barkema *et al.,* 1999; Chaplin *et al.,* 2000b). Furthermore, milk cell-count and the incidence of mastitis are important indicators of the health of housed cattle (Fregonesi and Leaver, 2001). In spite of the outdoor animals being dirtier there was no difference between treatments in the number of clinical or sub-clinical cases of mastitis during the first four weeks of lactation.

Behaviour

An animals demand for lying is characterised by a considerable degree of elasticity and therefore it has not been possible to establish cows' need for lying in terms of a minimum

total lying time per day (Wierenga and Hopster, 1990). Leonard et al. (1996) reported mean lying times of 10 hours per 24 hour period for first lactation animals. In the current study heifers in all treatments were lying for on average 50% of the 24-hour periods during which they were observed. This corresponds to about 12hours per day which is higher than that recorded by Leonard et al. (1996). During pregnancy heifers housed outdoors and modified heifers indoors spent less time lying during 24 hours than the control animals. The animals outdoors also stood more during early lactation, although these observations were only conducted over 12 hour periods and may not have been representative of the total time spent lying. In relation to the outdoor animals these findings are in contrast to research that reported a decrease in lying behaviour in indoor housing compared to pasture (Singh *et al.,* 1993a). Indeed, Fisher *et al.* (2003) reported similar lying times for dairy cows while at pasture and housed on a wood chip stand-off pad. While the woodchip surface of the out-wintering pad was probably as comfortable as pasture the difference in lying behaviour in the present study can be largely attributed to the time of year. Indeed, the behaviour of the heifers on the out-wintering pad was greatly affected by the weather and the expression of certain behaviours varied considerably depending on the prevailing conditions. For example, as previously mentioned there were no incidences of outdoor heifers lying down during the observation conducted 3 weeks after housing. This observation coincided with a period of high wind and heavy rainfall. The heifers responded to these conditions by standing huddled together on the concrete area during the entire 12-hour observation. A high frequency of weight shifting, which is indicative of tiredness and discomfort (Ruckebusch, 1974), accompanied the prolonged time spent standing. Hence on this day low levels of lying were certainly indicative of poor welfare. A reduction in time spent lying down as a result of poor environmental conditions can impact on other normal behavioural activities of dairy cows. For example, the time spent lying down ruminating is significantly positively related to the time spent lying down (Singh *et al.,* 1994). This explains why outdoor heifers spent less time sleeping and ruminating while lying relative to indoor heifers.

Reduced lying is generally interpreted as an indication of poor welfare (e.g. Fisher *et al.,* 2003) and poor cow comfort (Miller and Wood-Gush, 1991; Krohn *et al.,* 1992). However, it is unlikely that reduced lying by the modified heifers relative to the control group corresponded to poor welfare. Instead of lying these animals spent longer standing in the passageway where the cushioned flooring was located. This suggests that they were comfortable standing because their feet were protected from the floor by the slat mats. Heifers in the modified cubicle system also spent longer feeding than outdoor or control animals although this did not translate to a difference in weight gain. It is plausible that heifers on the modified treatment simply spent more time sifting through the available feed in search of the freshest silage or concentrate, thus the increased time spent feeding did not result in an increase in productivity. The reason for this could initially be explained by the presence of the cushioned flooring at the feed face. However, the difference persisted once the rubber was removed which is difficult to explain.

Performance

The average daily liveweight gain of the outdoor heifers during pregnancy, although lower than that of indoor heifers, was 0.7kg per day which is above the 0.6kg per day target weight gain recommended for pregnant dairy heifers by the Teagasc advisory service. The outdoor heifers experienced a growth check relative to the heifers housed indoors during the period of bad weather towards the end of November. Mogensen *et al.* (1997) suggests an association between production and behaviour. Excessive standing in itself can adversely affect weight gain in cattle (Mogensen *et al.,* 1997), possibly due to the increased energetic cost of standing and the negative effects of stress hormone activation on anabolic metabolism (Fisher *et al.,* 2003). Mogensen *et al.* (1997) also observed a correlation between lying periods and daily gain in which heifers with fewer lying periods also had low daily gain. Moreover, under cold conditions, a muddy lying surface is particularly detrimental

to cattle productivity and thermal comfort (Morrison *et al.,* 1970; Holmes *et al.,* 1978). A combination of these factors may have contributed to the growth check in the outdoor heifers. Contrary to the results of the present study however, Hickey *et al.* (2002) found that beef cattle accommodated outdoors had a higher daily liveweight and carcass weight gain and feed intake. Beef animals have higher muscle and subcutaneous fat depth, thus reducing the impact of weather conditions on behaviour and production. Furthermore, these animals produced significantly more heat from the digestion of their food then required to maintain body temperature (Hickey et al., 2002). This further protected them from cold stress. In contrast, the heifers would have been diverting most of their energy to growth and development of the foetus during the last 60 days of pregnancy. In addition, these animals were still growing which would have placed an additional demand on their resources. Nevertheless, there was no effect of treatment on the body weights of heifers during the first four weeks of lactation. The last weighing of all groups of heifers was in early January when all animals were still pregnant. However, many of the heifers did not calf until March. There was a dramatic improvement in the weather between January and March that year so weight gains of the outdoor animals probably improved during this period.

In light of the lack of a difference in the body weights of heifers during early lactation it is not surprising that there was no effect of treatment on milk yield or milk composition. For lactating animals, blood flow to the mammary gland is increased during lying (Metcalf et al., 1992; Rulquin and Caudal, 1992) and when cows are deprived of lying, plasma concentration of growth hormone is reduced which is likely to affect milk production (Munksgard and Lovendahl, 1993). Therefore, even though the outdoor heifers lay less during lactation they were not so deprived of lying as to adversely effect milk production.

Immune function

A reduction in interferon gamma production in response to in vitro stimulation with a mitogen in conjunction with a reduction in lymphocyte and an increase in neutrophil percentages is indicative of reduced immune function (Earley et al., 2002). Interferon gamma (INF-γ) production in response to PHA and CON A was reduced in the outdoor heifers compared to those housed in both indoor housing treatments on week 6 and week 10 relative to the start of the experiment. However, this reduction was not significant. Indeed, haematology results from blood samples taken around this time did not indicate substantial increases in neutrophil and decreases in lymphocyte percentages, typical indications of immunosuppression. Nevertheless, outdoor heifers had higher white blood cell counts (WBC) throughout the housing period. Several studies report an increase in WBC in response to castration in cattle (e.g. Fisher et al., 1997) suggesting that high levels are indicative of stress. Of more significance is the fact that the outdoor animals had higher numbers of neutrophils in circulation throughout the housing period. Neutrophils are the first line of defence and play a major role in removing invading bacteria. Previous studies using transport as a stressor demonstrated that stress could result in profound neutrophilia (Yagi et al., 2004) in addition to modulation of function (Blecha and Baker, 1986; Murata et al., 1987). These findings indicate that animals outdoors were immunosuppressed to some degree relative to their counterparts indoors. This was probably caused by cold stress during periods of bad weather.

Conclusions

There were indications that the slat mats resulted in some improvements to hoof health and heifer comfort indoors. This could have important implications for the longevity of dairy cows housed in cubicle systems. However, there is a greater potential for improved welfare on out-wintering pads than through the provision of cushioned flooring in cubicle housing as evidenced by lower hoof and injury scores in outdoor animals. Although out-wintering affected several of the indicators measured, activity budgets and bodyweights of all heifers

fell within recommended ranges. The problems associated with the pad included a reduction in weight gain relative to the animals indoors, dirtiness and immuno-suppression. None of these had a negative effect on animal health or production and all were probably weather and management dependent. Hence, it is likely that they could be ameliorated through the provision of shelter and more frequent cleaning of the pad surface and/or a reduction in stocking density.

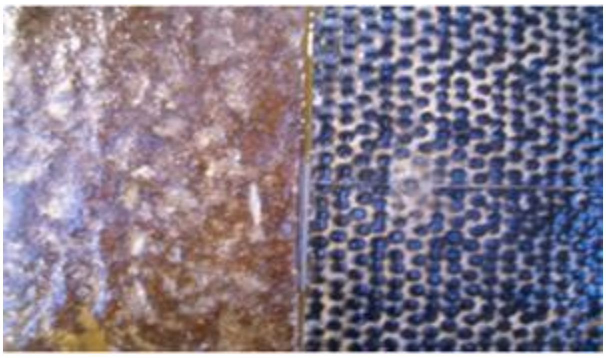
Effect of floor surface on behaviour, welfare and reproduction of dairy cows in cubicle housing

Materials and methods

Animals and housing

Sixty-two cows were blocked on expected calving date (ECD), previous milk yield and parity. Cows from each block were assigned randomly to 2 treatments (CONCRETE or MAT) at least 3 weeks prior to ECD until at least 16wks post-partum (PP). A house with mattress-bedded cubicles (Pasture Mat®, O'Donovan Engineering, Coachford, Co. Cork) and an automatic scraper was divided in two. On one side the concrete flooring in the passageways and in front of the feed face was covered with rubber flooring (R.J. Mooney Anti-Lameness Mat®) [i.e. MAT]. On the other side the concrete was not covered. The scraper cleaned both floors approximately once per hour. Cows were removed from their respective treatments to a straw-bedded calving pen approximately 24-48 hours before calving until the first milking when they were returned to the cubicle house.

Cubicle house with gate dividing the concrete (near) and rubber flooring (far) areas



Close up of the juncture between the concrete and rubber flooring (RJM Anti-Lameness Mat®)

Foot lesion scoring (see photographs in previous section)

The hind feet of all cows were evaluated and correctively trimmed in July 2003. Thereafter each animal was examined at housing, 1, 7 and 12 weeks post-partum. All four hind claws were cleaned and lightly trimmed in a restraining chute. A sliver of horn was pared from the whole area of the weight-bearing surface to expose fresh horn. Haemorrhages were localised as to 6 zones of the sole and white line. The severity of haemorrhages observed in each zone was scored on a 4 point scale as per Vermunt and Greenough (1991). The scores for the 6 zones of all four claws were added to give a total sole and white line bruise score for each animal at each inspection. The presence of dermatitis and heel horn erosion was determined by gross examination of the plantar/palmar area of the skin and the bulb area of all claws. The severity of these lesions was rated on a three-point scale and added to give a heel erosion and dermatitis score for each cow.

Locomotion scoring

Cows were assessed when walking over a fixed distance on a level concrete surface. Assessments were made prior to housing and thereafter on weeks 1, 7, 12 and 16 post-partum. Subjective scoring of locomotion on a 5-point numerical scale as per Manson and Leaver (1988) was adopted. If an animal exceeded the requirements of a particular score but did not meet all the requirements of the next successive score, a half-integer score was allocated. Cows receiving a score of 3 or more were considered clinically lame.

Animal behaviour

The behaviour of all cows in each treatment was monitored by instantaneous scan sampling over 24 hours once per week on Wednesday from three weeks pre-partum until 12 weeks post-partum. The activity (ruminate, feed, sleep, idle, active), posture (ventral/lateral lying, standing) and location (cubicle number, passageway, feeding stall) of all animals in each of the housing treatments were recorded onto a checklist every 15 minutes during the following time periods: 0830-1100h, 1200-1500h, 1630-1900h, 2000-2300, 2400-0230 and 0430-0700h.

Oestrous activity

Onset of oestrous activity was recorded as the first recorded oestrus post partum. Oestrus events were recorded by both visual observations using tailpaint and by radiotelemetry. Tailpaint was applied to all animals approximately one week after calving on the same day each week. Visual observations were carried out at least three times daily for 30 minutes from one week after calving. Radiotelemetry was used in conjunction with visual observations. The cows' tailhead area was shaved two weeks before expected calving date. The Heatwatch® radiotelemetric (HW) transponders were glued in place at the time of first tailpainting one week after calving. Standing oestrous was defined by HW as >3 mounts in 4 hours of >1 second duration and suspect oestrus as <2 mounts in 4 hours. A HWSO of low intensity and low duration (LILD) was defined as one of <7 h and <10 mounts. The size of the sexually active group (SAG) was defined by the number of cows in HWSO simultaneously. Milk sampling was carried out to detect false oestrous events (>3 HW mounts within 4 hrs with high, >3 ng/ml, milk progesterone concentration). True SO was recorded where a HWSO was recorded with an MP4 value <3 ng/ml and unless otherwise stated, all HW results refer to True SO. A milk sample was collected on the day of (am or pm), or the day after (am) any cow had >1 HeatWatch mounts. Samples were preserved with a Lactab Mark 111, stored at 4oC and analysed in batches for progesterone concentration at Ridgeway Science, UK. Intra- and inter-assay coefficients of variation for

the EIA were 6.1% and 6.5%, respectively. The sensitivity, calculated using absorption of the blank standard minus two standard deviations, was 0.5 ng/ml.

Breeding management

At the pre-breeding examination (24 November 2003) ten days before the mating start date (4 December 2003), problem cows (ovarian cysts, moderate/severe endometritis, but not anovulation) which were >35 days after calving), were treated, as appropriate. Late calvers were scanned in batches pre-breeding, as they were >35 days calved, and managed as above. Cows were served at standing oestrus, using both visual and HeatWatch data, without synchrony, without a voluntary waiting period (VWP). On day 35 of the breeding season (5th January 2004), all cows that had not been observed in oestrus and served and were >35 days calved were examined and treated, as appropriate. This allowed potentially at least two services before the mating end date (24th February). Cows were examined at 30 and 60 days after AI for pregnancy. Cows which were not pregnant were treated, as appropriate, to ensure rapid re-service. The breeding season lasted 12 weeks (82 days). A final pregnancy examination was carried out one month after the mating end date. One commercial AI technician performed all AI. Natural service was not used. A single ejaculate from one sire (code DXD) of known fertility (semen analysis: 60:40 alive:dead sperm; motility: good) was used to serve all cows at first and second services and all except five subsequent inseminations. Oestrus events and conception data were recorded on a notice board breeding chart and entered into Microsoft Excel spreadsheets.

Statistical analyses

Data were analysed by analysis of variance, with repeated measures as appropriate, using Proc GLM and Proc MIXED or by chi-square using Proc FREQ in SAS. The models included terms for treatment, time, interactions and block. As the radiotelemetry data were non-normally distributed (Proc UNIVARIATE) with repeated measures and missing data, they were transformed using log10 (number of mounts received) or square root transformation (duration of standing oestrus). The transformed data were analysed using Proc MIXED with pair-wise comparisons by Tukey's procedure and the back-transformed means plus 95% confidence intervals (C.I.95) are presented. Data on locomotion scores were analysed using the frequency procedure of SAS.

Results

There was no effect of rubber flooring on sole/white line bruises or dermatitis scores (Table 1). There was a time*treatment interaction for heel erosion scores (P<0.05). CONCRETE cows had higher heel erosion scores 7 weeks post-partum compared to MAT cows (P<0.05).

Table 1. Effects of floor surface on sole bruise, dermatitis and heel erosion scores (lsmean±s.e.)

Inspection	Concrete			Mat		
	Sole bruise	***Dermatitis***	***Heel erosion***	***Sole bruise***	***Dermatitis***	***Heel erosion***
Pre-partum	5.1 ±	1.0 ± 0.31	1.6 ±	4.8 ±	1.6 ± 0.34	1.0 ±

Table 1. Effects of floor surface on sole bruise, dermatitis and heel erosion scores (lsmean±s.e.)						
Inspection	**Concrete**			**Mat**		
	Sole bruise	***Dermatitis***	***Heel erosion***	***Sole bruise***	***Dermatitis***	***Heel erosion***
	0.57		0.29	0.63		0.32
1 week pp	5.1 ± 0.57	0.6 ± 0.19	3.9 ± 0.32	4.8 ± 0.63	1.3 ± 0.22	3.7 ± 0.35
7 weeks pp	4.0 ± 0.53	1.4 ± 0.23	5.8 ± 0.39[a]	4.2 ± 0.59	2.0 ± 0.25	4.5 ± 0.43[b]
12weeks pp	4.0 ± 0.47	1.5 ± 0.32	5.8 ± 0.34	2.7 ± 0.52	2.0 ± 0.35	5.5 ± 0.37
16 weeks pp	5.8 ± 0.63	1.9 ± 0.26	5.9 ± 0.25	6.0 ± 0.69	2.2 ± 0.29	6.3 ± 0.27

[a,b] $P<0.05$

There was no effect of treatment on the proportion of cows in each treatment that had abnormal locomotion scores (i.e. scores greater than 1) (Table 2).

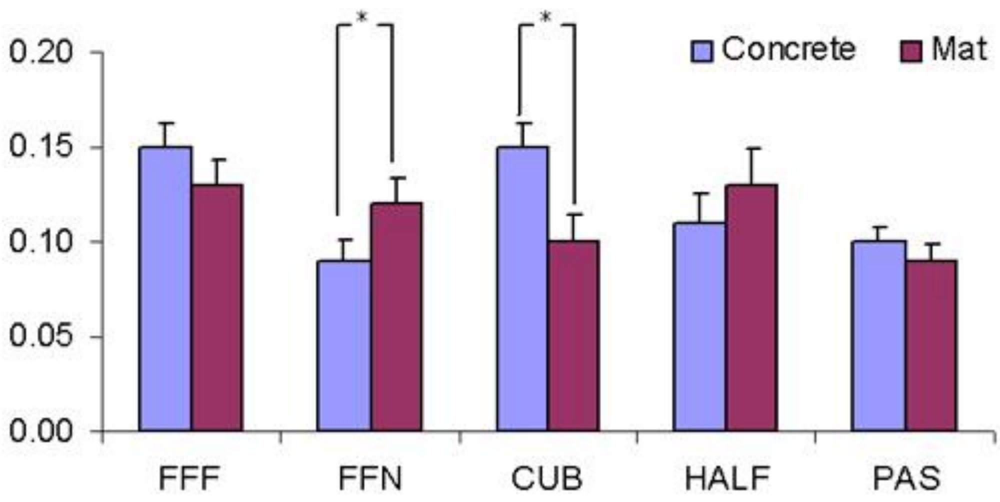
Table 2. Effect of floor surface on percentage of cows (no. affected/total no. inspected) with abnormal locomotion (i.e. cows with locomotion scores >1]) at 5 inspections			
Inspection	**Concrete**	**Mat**	**P**
Pre-housing	16 (4/25)	19 (4/21)	NS
1 week post-partum	25 (8/32)	23 (7/30)	NS
7 weeks post-partum	6.5 (2/31)	13 (4/30)	NS
12 weeks post-partum	3.3 (1/30)	6.9 (2/29)	NS
16 weeks post-partum	3.7 (1/27)	0 (0/27)	NS

There were no effects of treatment on time spent standing or lying or time spent engaged in different behaviours during pregnancy or lactation (Table 3).

Table 3. Effect of floor surface on behaviour (lsmean±s.e.) of cows during pregnancy and lactation				
Behaviour	**Concrete**		**Mat**	
	Pregnancy	**Lactation**	**Pregnancy**	**Lactation**
Stand	0.60 ± 0.020	0.62 ± 0.014	0.58 ± 0.023	0.62 ± 0.015
Lie	0.40 ± 0.020	0.38 ± 0.014	0.42 ± 0.023	0.38 ± 0.015
Feed	0.15 ± 0.012	0.17 ± 0.007	0.13 ± 0.013	0.17 ± 0.007
Sleep	0.02 ± 0.003	0.03 ± 0.001	0.02 ± 0.003	0.03 ± 0.002
Idle	0.32 ± 0.016	0.30 ± 0.010	0.36 ± 0.018	0.31 ± 0.011
Ruminate	0.39 ± 0.010	0.41 ± 0.007	0.35 ± 0.015	0.39 ± 0.007
Active	0.11 ± 0.008	0.10 ± 0.004	0.13 ± 0.009	0.10 ± 0.005

During pregnancy MAT cows were observed standing close to the feed face, but not feeding, during a higher proportion of observations while there was a higher proportion of observations of CONCRETE cows standing in the cubicles (Figure 1). There was no effect of treatment on the location of cows while standing during lactation (data not shown).

Figure 1. Effect of floor surface on location of cows while standing (lsmean±s.e.) during pregnancy



FFF=Feeding at face feed; FFN=Close to feed face but not feeding; CUB=Cubicle; HALF=Partially in cubicle; PAS=Passageway between rows of cubicles

* P<0.05

Floor surface had no significant effect on standing oestrus events detected by observation and tail paint prior to the mating start date (MSD) (Table 4).

Table 4. Effect of floor surface on standing oestrus events (mean±sd; % (No.)) detected by visual observation and tail paint prior to the mating start date

Index	Variable	Concrete	Mat	P
Cows (No.)		32	30	-
Calving	Calving date	18 Oct. (29)	15 Oct. (30)	NS
First oestrus	Calving to first observed oestrus pre-AI (d)	35.1 (16)	47.1 (18)	NS
	Cows with calving to first observed oestrus pre-AI <45 d	41 (13/32)	23 (7/30)	NS
Oestrus dates	First oestrus	5 Nov (14)	9 Nov (13)	NS
	Second oestrus	17 Nov (14)	13 Nov (12)	NS
	Third oestrus	-	27 Nov (-)	-
Oestrus events per cow	Oestrus events per cow	0.59 (0.71)	0.52 (0.78)	NS
	Cows with an oestrus event	47 (15/32)	37 (11/30)	NS
Repeat intervals	Oestrus 1 to oestrus 2 (No.)	4	3	-
	Oestrus 1 to oestrus 2 (d)	16.5 (7.2)	19.8 (11.4)	NS
	Oestrus 1 to oestrus 2 = 18-24 d (No.)	2	1	NS

Floor surface also had no significant effect on standing oestrus (SO) events detected by radiotelemetry prior to and during the breeding season (Table 5). There were no significant interactions between treatment, oestrus number (1-4) and the number of cows in oestrus simultaneously (sexually active group; SAG, 1-6), hence only treatment effects are shown. The duration of SO (28-1297 mins.) increased with each succeeding oestrus (SO1 v SO3; 292.6 (203.69-397.48) v 489.0 (249.73-807.80), (P<0.104), (SO1 v SO4; 292.6 (203.69-397.48) v 572.8 (260.63-1006.24), (P<0.089) but was unaffected by the size of the SAG. The number of mounts received during an SO (3-24) was unaffected by oestrus number or the size of the SAG. The inter-oestrus interval (6-72d) was unaffected by oestrus number or the size of the SAG. False SO was uncommon (5.2%, 4/77 SO) and in one case involved a borderline milk progesterone concentration (3 ng/ml) and in another a cow that repeatedly had difficulty in rising in the cubicles and so may have false mount data.

Table 5. Effect of floor surface on standing oestrus events (ls mean±se; % (No.)) detected by HeatWatch (HW) radiotelemetry				
Index	**Variable**	**Concrete**	**Mat**	**P**
Cows	No. cows	24	22	-
True SO	HW standing oestrus (HWSO) and milk progesterone < 3ng/ml (No.)	37	36	NS
Oestrus duration	Duration of true SO (mins.)*	437.3 (302.95, 596.11)	424.3 (286.84, 588.60)	NS
Mounts received	Mounts received during true SO (No.)*	7.0 (5.14, 9.42)	8.0 (5.78, 10.96)	NS
LILD SO	Low intensity, low duration SO	67 (25/37)	53 (19/36)	NS
SAG	Size of sexually active group (No.)	2.3 (0.34)	2.0 (0.32)	NS
IOI	Inter-oestrus interval (d)	35.9 (5.45)	30.7 (5.86)	NS
HWVis	True SO also recorded by visual observation	70 (26/37)	75 (27/36)	NS
False SO	HWSO but milk progesterone ≥ 3ng/ml	2.6 (1/38)	7.7 (3/39)	NS

*backtransformed mean (C.I. 95)

Cows on the CONCRETE flooring had significantly more reproductive problems prior to breeding than those on the MAT floor (Table 6).

Table 6. Effect of floor surface on reproductive problems prior to service (mean±sd; % (No.)) detected by ultrasonography				
Index	**Variable**	**Concrete**	**Mat**	**P**
Cows	No. cows	32	30	-
Cv-scan	Calving to scan interval (d)	47 (16.2)	47 (17.5)	NS
AA	Anovulatory anoestrus	25 (8/32)	10 (3/30)	NS
Cyst	Follicular cyst	9.4 (3/32)	6.6 (2/30)	NS

Table 6. Effect of floor surface on reproductive problems prior to service (mean±sd; % (No.)) detected by ultrasonography				
Index	**Variable**	**Concrete**	**Mat**	**P**
	Luteal cyst	6.3 (2/32)	0	NS
Endo	Subclinical endometritis (score 3)	25 (8/32)	17 (5/30)	NS
	Pyometra (score 5)	16 (5/32)	10 (3/30)	NS
UV	Urovagina	3 (1/32)	3 (1/30)	NS
Total cows % (No.)		72 (23/32)	40 (12/30)	<0.05

Floor surface had no significant effect on reproductive performance during the breeding season (Table 7).

Table 7. Effect of floor surface on reproductive performance (mean±sd; % (No.)				
Index	**Variable**	**Concrete**	**Mat**	**P**
Cows (No.)		32	30	-
Cv-MSD	Calving to mating start date interval (d)	46 (29.3)	49 (29.4)	NS
Late calvers	Cows calved ≤30d pre MSD	35 (11/32)	27 (8/30)	NS
COI	Calving to first observed oestrus interval (d)	49 (25)	57 (25)	NS
SR	Submission rate-21d	50 (16/32)	60 (18/30)	NS
CSI	Calving to first service interval (d)	70 (21)	72 (23)	NS
CCI	Calving to conception interval (d)	80 (21)	89 (34)	NS
FSCR	Date of first AI	28/12 (19)	25/12 (16)	NS
	First service conception rate	52 (15/29)	48 (14/29)	NS
SSCR	Date of second AI	11/1 (15)	12/1 (13)	NS
	Second service conception rate	38 (3/8)	47 (7/15)	NS

Table 7. Effect of floor surface on reproductive performance (mean±sd; % (No.)				
Index	**Variable**	**Concrete**	**Mat**	**P**
AI/cow	No. of services per cow	1.34 (0.83)	1.72 (0.84)	NS
LEM	Late embryonic mortality (30 to 60 d)	3.4 (1/29)	0/29	NS
6wkPR	Six-week pregnancy rate	56 (18/32)	47 (14/30)	NS
Overall PR	Overall pregnancy rate	66 (19/29)	68 (19/28)	NS

Reproductive problems prior to service were significantly more likely to be associated with non-pregnancy in the cows in the CONCRETE group compared to cows in the MAT group (Table 8).

Table 8. Effect of floor surface on factors associated with non-pregnancy				
Index	**Variable**	**Concrete**	**Mat**	**P**
Cows (No.)		13	11	-
Problems	Pre-service reproductive problems	10/13	4/11	<0.05
RB	Repeat breeders	1/13	2/11	NS
LateCv	Late calving cows	1/13	0/11	NS
Other	Misc., embryonic loss, culled, died	1/13	5/11	NS

Discussion

In contrast to studies that found a beneficial effect of housing on straw around calving (e.g. Webster, 2001; Laven and Livesey, 2004) on sole lesions post-partum, there was no effect of rubber flooring on sole and white line bruise scores. These findings agree with the previous study described in this report and suggest that the cushioning properties of rubber flooring are not as good as that of straw. Although dermatitis is an infectious condition it is influenced by environmental factors especially hygiene (Webster, 2002b). Hence, the lack of difference in dermatitis scores could be explained by the fact that the rubber flooring was as dirty as the concrete. Heel erosion is caused by a combination of chemical and mechanical erosion. The fact that MAT cows had lower scores 7 weeks post-partum suggests that the rubber flooring helped to protect the heels from mechanical erosion during early lactation. This agrees with the findings of the previous study. Heel horn erosion is rarely a cause of lameness in itself but eroded heels trap dirt and stones that can penetrate the sensitive area of the foot and lead to infection.

Rubber flooring did not increase the time spent eating. This is in agreement with several studies (Stefanowska et al. 2001; Fregonesi et al., 2004). It appears that cattle maintain eating times even when conditions at the feed bunk are less than optimal (Friend et al., 1976). Nevertheless, the heifers on cushioned flooring in the first study in this report spent longer feeding although the cushioned flooring was not in place at the feed face for the duration of that experiment. However, there was a major difference in time spent feeding between the two studies. The heifers spent about 30% of their time feeding compared to only 15-20% of time spent feeding by the cows in the current study. One reason for this could be that while all the heifers could feed simultaneously, the cows had to wait their turn for access to a feed box. There was agonistic behaviour associated with competition for access to a feed box which could have made the cows reluctant to spent any more time than necessary feeding. Nevertheless, the cows spent more time standing near the feed face when covered by rubber flooring which agrees with Fregonesi et al. (2004). This corresponds to the finding in the former study that heifers on cushioned flooring spent longer standing in the passageway then control animals. In the current study cows on concrete spent more time standing in the bedded cubicles. This indicates that in the absence of comfortable flooring for standing in the passageways, cows used the bedded cubicles for standing instead. The fact that cows in both treatments had the option of getting relief for their feet from the concrete also explains the lack of a difference betweens treatments in sole bruising.

Locomotion scores indicated no effects of housing system on lameness. However, O'Callaghan et al. (2003) suggests that pain arising from foot lesions is often masked by the stoical nature of cattle, resulting in delayed detection of lameness. Thus, simple locomotion scoring systems may fail to detect subtle changes in posture and weight bearing which might relate to pain experienced by the individual animal.

Flooring surface had no significant effect on standing oestrus events detected by visual observation and tail paint prior to the start of the breeding season. It might be speculated that if cushioned flooring reduced solar bruising (haemorrhages), this might increase cow comfort during oestrous activity, whether mounting or being mounted, and hence, increase oestrous detection efficiency. However, cushion flooring did not reduce the incidence of solar bruising. The fact that the rubber flooring was probably as slippery as the concrete may also account for the lack of a treatment difference in oestrus events. The grip afforded by floor surface is likely to have a critical effect on cow-to-cow interactions during standing oestrus, with surfaces with a high grip coefficient resulting in more intense and prolonged oestrous behaviour (Larkin et al. 2003, Britt et al., 1986, De Silva et al., 1981).In general, oestrous detection efficiency was low, with only 42% of cows (26/62) detected in oestrus prior to the MSD and only 0.6 (sd 0.74) oestrus events detected per cow, for all cows. This was due to short interval between calving and MSD (mean±sd: 48±29.2d), the efficiency of visual observation and tail paint in detecting standing oestrus (73%, 53/73 HeatWatch SO (HWSO) detected by visual observation and tail paint) and the incidence of anovulatory anoestrus prior to the MSD (18%, 11/62) and suboestrus prior to and during the breeding season (66% of HWSO were <7 h, 48/73; 77% of HWSO had <10 mounts, 56/73) in these autumn-calving dairy cows. Numerical differences between groups may reflect real differences, which could not be detected as statistically significant due to limited experimental units, or chance effects accentuated by percentage figures with small numbers. The large variation within groups, as shown by the large standard errors, indicate that numerical differences between groups are not likely to reflect treatment effects.

Flooring surface also had no significant effect on standing oestrus events detected by radiotelemetry prior to and during the breeding season. These data provide a more complete picture of oestrous behaviour on the two flooring surfaces throughout the entire day compared to visual observations but these data are not available to commercial dairy farmers. The lack of difference between treatments is not surprising given the results from

visual observations and tail paint. Larkin et al. (2003) showed that duration of oestrus and number of mounts detected by telemetry were similar on rubber-covered slats, pasture and straw and significantly increased compared to concrete slats. Though this comparison showed that oestrous activity in beef animals was greater on rubber-covered slats compared to concrete slats, the construction of the raised rubber covering provided some resistance to slippage in addition to cushioning. The former attribute of the rubber covered slat, absent in the rubber covered floor, in addition to differences in rubber consistency, may have been contributory factors to differences in oestrous activity. Modification of the rubber mat to include deep grooving or raised ridges may increase its coefficient of friction and thus improve slip resistance. Overall, both the duration of (431.45; 309.73, 573.31mins.) and number of mounts received during standing oestrus (7.38; 5.93, 9.73) were low and the majority of SO (60% (44/73) were of low intensity and low duration indicating suboestrus was common in these cows. This may reflect the slippery underfoot conditions, the high genetic merit for milk yield and milk yield of these cows and the relatively small sexually active groups (mean±sd 2.0±1.36 cows) in the absence of oestrous synchrony.

The finding that cows on the CONCRETE flooring had significantly more reproductive problems prior to breeding than those on the MAT floor could not be attributed to differences in the incidence of cows with calving problems (dystocia, malpresentation, retained placenta: CONCRETE 22% 7/32, MAT 23% 7/30) or to differences in calving to examination intervals. More cows in the CONCRETE group were anoestrus, had ovarian cysts or endometritis/pyometra prior to breeding. Some of these risk factors contributed to non-pregnancy during the breeding season.

Floor surface had no significant effect on reproductive performance during the breeding season. In the absence of differences in oestrous behaviour and oestrous detection rates, it is not surprising that differences in reproductive performance were not detected. Overall reproductive performance was poor, but not untypical of autumn-calving herds (Mee, 2005). A combination of late calving cows (31%, 19/62) and suboestrus led to a low submission rate in the first three weeks of breeding (55%, 34/62). Conception rates to first (50%, 29/58) and second services (43%, 10/23) were low, which combined with a low submission rate resulted in a low six-week pregnancy rate (50%, 32/62). This combined with suboestrus at repeat oestrus events and a short breeding period resulted in some cows not receiving enough services and non-pregnancy. This is reflected in the low number of services per cow (mean±sd 1.56±0.941) and the low overall pregnancy rate (67%, 38/57). Problems prior to breeding were associated with non-pregnancy in the majority of non-pregnant cows (58%, 14/24) and these problems were more common in the CONCRETE group compared to the MAT group. Given that these pre-breeding conditions represent a disparate range of reproductive problems, it is not clear from this study as to why this should be so.

Conclusions

The rubber flooring had only negligible beneficial effects on hoof health and no effect on oestrous events or reproductive performance. Where well bedded, appropriately sized and designed cubicles are provided, cows can use them for standing to get relief from the concrete. Grooves in the rubber flooring would help to improve its traction.

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Publications

- **Boyle, L.A., Mee. J.F., M. O'Donovan and Kiernan, P.J.** (2005). Effect of out-wintering on an out-wintering pad and providing cushioned flooring in cubicle housing on the behaviour, welfare and reproductive performance of dairy cattle. End of Project Report No. 5139
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