Final Thesis

Behaviour, welfare, performance and climatic energy demand of yearling dairy heifers on two nutritional levels, out wintered on an all-weather pad or housed indoors in cubicles

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Contents

1 Abstract

Housing cattle indoors on concrete floors has negative welfare implications and has high economic costs. The aim of this experiment was to evaluate the behaviour, welfare, performance and climatic energy demand of yearling dairy heifers on two levels of nutrition kept on an out-wintering pad or indoors in cubicles. Ninety-six yearlings, were blocked and assigned to one of four treatments in groups of eight: a) indoors, silage only b) indoors, silage plus concentrate c) outdoors, silage only d) outdoors, silage plus concentrate. All animals were inspected for lesions at the beginning and end of the trial. Instantaneous and continuous recording by direct observation were used to collect data on behaviour. Animals were weighed and body condition scored and feed intakes were recorded. There were significantly more comfort, social and play behaviours recorded outdoors ($P<0.01$). Trips/slips and falls were only recorded indoors ($P<0.01$). Nutrition had no effect on these parameters. There was no effect of housing or nutrition on time spent standing or lying ($P>0.05$). Fewer yearlings outdoors were affected by limb lesions ($P<0.001$) but they were dirtier than animals indoors ($P<0.05$). Yearlings outdoors had significantly lower average daily weight gains and body condition scores ($P<0.05$), which was partly explained by lower intakes. However, their performance did not fall below recommended targets. Furthermore, heat loss did not exceed heat production for any of the animals. In conclusion, the out-wintering pad was associated with significant improvements to animal welfare and did not compromise performance.

Keywords: Behaviour, dairy cattle, housing systems, out-wintering, welfare

2 Introduction

In spite of their obvious importance in determining future production levels replacement dairy heifers are often assigned the poorest housing conditions on Irish farms (O'Connell *et al*., 1993). Winter housing for such animals varies greatly within and between countries in Europe. However, they are generally housed indoors, often in pens on slatted concrete floors, which are associated with many welfare problems (Livesey *et al*., 1998; Webster, 2001), including lameness (Singh *et al*., 1993). Lameness in dairy cattle is a significant welfare problem and incurs high economic costs (Singh *et al.*, 1993; Livsesy *et al*., 1998; Galindo *et al*., 2000). Lameness in cattle is regarded as a multifactorial problem, but housing is one of the major factors involved (Leonard *et al.*, 1994; Galindo *et al.*, 2000; Vokey *et* al., 2001). A number of studies have shown the association between incidences of lameness and various types of housing. For example, Frankena *et al.* (1992) found that calves housed on straw beds had a lower incidence of sole haemorrhages compared to calves housed on slatted floors. The fact that dairy animals can be affected by such lesions at such a young age raises concern as this could predispose them to foot problems during their productive lives (Frankena *et al.*, 1992).

Characteristics of intensive farming systems such as concrete flooring can have an effect on the behaviour of animals (Albright and Arave, 1997; Galindo *et al.*, 2000) along with causing trauma to joints and limbs (Frankena *et al.*, 1992). Concrete floors often become slippery and uneven over time (Albright and Arave, 1997; Fraser and Broom, 1997). As a consequence, an animal's locomotion and social behaviour, which are often performed in connection with each other, are restricted due to the risk of slipping (Albright and Arave, 1997). Furthermore, due to high construction costs and high stocking densities of intensive units space is often limited. Lack of space can also affect the occurrence and quality of locomotor and play behaviours (Jensen *et al.*, 1998; Hanninen *et al.*, 2003). Such behaviours, especially play behaviour among young cattle may be used as an indicator of the presence of good welfare and the presence of positive feelings (Fraser and Broom, 1997; Jensen *et al.*, 1998; Jensen and Kyhn, 2000). According to Fraser and Broom (1997) juveniles are highly motivated to play once their basic needs have been met. Furthermore, play in young animals is highly beneficial, as it aids their physical and social development. An experiment conducted by Fregonesi and Leaver (2001) showed how housing could affect play behaviour, they found that cows moved from cubicles to a straw yard displayed a greater incidence of play behaviours than cows moved from a straw yard to cubicles. Other behaviours such as grooming are considered to be of great significance when evaluating housing conditions. In particular caudal licking, since the animal is unstable while carrying out the behaviour and in danger of slipping (Jungbluth *et al.*, 2003). These authors found more caudal licking where the floors were covered with rubber mats and the animals were able to perform such behaviour without slipping. In essence, the absence of behaviours like play and grooming may indicate poor welfare of animals. Therefore, an essential feature of alternative housing needs to take into consideration the ability of animals to perform a more natural behavioural repertoire (Redbo *et al.*, 1996) without compromising the health of the animal and the production and economic costs (Hickey *et al.*, 2002).

There is currently much interest in low cost ‘housing’ systems such as out-wintering pads particularly among small to medium sized producers in Ireland. Survey data shows that these producers generally have very poor dairy housing facilities on their farms. The number of small to medium sized producers in Ireland dropped by 40% over the past decade and this decline will continue in the future. In order for these producers to survive they need low overhead cost structures with increased labour efficiency. Hence out-wintering pads (OWP) are likely to form part of a sustainable, high margin system of spring milk production in the future. According to some authors the health and welfare of animals may be improved by out-wintering on all-weather pads (Hickey *et al*., 2002; Kiernan, 2004).

Over forty years ago, Irish researchers investigated the concept of maintaining animals outdoors during the winter (McCarrick and Drennan, 1972). These authors found no differences between the winter live weight gains of young beef cattle (nine month old British Friesians) accommodated indoors, or outdoors on sawdust pads. These results are in agreement with findings on Friesian yearlings out wintered in a grass field and fed silage, which grew as fast as similarly fed animals indoors (Walshe, 1966; Gleeson and Walshe, 1967 and 1968). In McCarrick and Drennans (1972) study, liveweight gains (LWG) were much lower (< 0.25kg per day) than what they would be for similar animals today. Nevertheless, the authors stressed that the most important finding from the experiment was the absence of a live weight gain response accruing from the provision of a roof over cattle. Indeed, Webster *et al*. (1970) concluded that in terms of the productivity of cattle maintained outdoors, the additional benefits likely to accrue from providing a housing environment are small and difficult to justify. In a Swedish study, Redbo *et al*. (1996) found no difference in growth rate of steers maintained outdoors over the winter compared to steers housed indoors in slatted pens. Furthermore, Hickey *et al*. (2002) found that steers accommodated on an out- wintering pad during an Irish winter actually had higher daily live weight and carcass gains, and feed intakes than animals housed indoors on slats.

Top performance in animals outdoors occurs in the thermoneutral zone (TNZ), which is the zone of optimal comfort (Wagner, 1988). In general, growing cattle, including those of dairy breeds, have very low lower critical temperatures (LCT), defined as the temperature above which the animal does not have to increase its heat production to maintain internal body temperature (Christopherson, 1985). Hence they are well adapted to the cold (Young, 1981). However, the point at which the LCT is reached is variable and does not necessarily occur at a specific temperature. The actual temperature at which the LCT is reached depends on such things as wind speed, length of hair coat, wet or dry hair, animal weight and level of production (i.e. lactation, pregnancy, growth) level of animal activity, dietary heat production or heat increment as influenced by type of diet or level of feed intake etc. Since one of the important variables determining hardiness against the cold is level of production, there are doubts as to whether relatively slow growing animals like dairy heifers can be kept outdoors without negative implications for their welfare and productivity and may pose a potential health hazard to young cattle (Hanninen *et al*., 2003). Hanninen *et al*. (2003) concluded that young dairy cattle, when exposed to extreme weather conditions, showed a decrease in activity and reduced their body area. However, because of the elasticity of the TNZ, environmental or dietary changes can be made to widen the TNZ and thus improve animal comfort. Furthermore, according to Hoffman (1969) failure to provide increased dietary energy during periods of cold weather could cause a reduction in average daily gain of up to 0.4 lb per day among dairy heifers. The climatic energy demand (CED) can be used to define the interactive relationship of meteorological and management/dietary variables on the energy demands of the animal (Higgins and Dodd, 1989; Arkin *et al*., 1991).

The objective of this experiment was to evaluate the behaviour, welfare, performance and climatic energy demand of yearling dairy heifers on two levels of nutrition kept on an out-wintering pad or indoors in cubicles.

3 Materials and Methods

3.1.1 Experimental design, animals and housing

The experiment was conducted in the south of Ireland at Teagasc, Moorepark Research Centre, between the 8th of November 2004 and the 13th of February 2005 (12 weeks). Ninety-six yearling dairy heifers from the Moorepark herd were blocked according to date of birth and body weight and assigned to the following treatments in a 2 x 2 factorial arrangement with three replicates:

- Indoors low nutrition - silage only
- Indoors high nutrition - silage plus 3 kg per head concentrate
- Outdoors low nutrition - silage only
- Outdoors high nutrition - silage plus 3 kg per head concentrate

Yearlings housed indoors were on solid concrete floors with individual cubicles (1:1 ratio) bedded with rubber mats and dusted daily with sawdust and lime. An automatic scraper cleaned the floor. Yearlings outdoors were on an out-wintering pad (OWP) with approximately eight square metres each and self fed from a concrete area beside the pad. The OWP was constructed with layers of graded stones and a deep layer of wood chip placed on top. Shelter against the prevailing wind was provided by erecting a two-meter high semi-porous barrier around two sides of the pad (Nicofence®, R.J.M. Mooney, & Son Ltd., Avonbeg Industrial Est., Dublin 12, Ireland). The pad was cleaned off once six weeks after commencement of the experiment and a fresh layer of wood chip was laid down. All animals were dosed for lice and parasites prior to the experiment.

At the start of the experiment all animals in each treatment were held together in one group for a week in order to habituate them to the housing conditions. Thereafter each treatment was divided into sections such that one section held eight yearlings and the other held the remaining sixteen yearlings. The OWP pad was divided into four sections 2 (13 m x 5 m) and 2 (13 m x 10 m). There were three replicates of eight yearlings in each treatment with each replicate being separated from the main group every two weeks (two week rotation). Data were collected on each replicate over two, two week periods during the experiment.

3.1.2 Feeding

The nutritional treatments were low nutrition: silage of 70 % DMD fed *ad lib* (targeted to gain 0.5 kg per head per day) and high nutrition: silage *ad lib* and 3 kg of an 18 % crude protein concentrate diet (targeted to gain approximately 1 kg per head per day) (high nutrition). All animals were fed once daily at approximately 1100 hrs.

3.2 Measurements

3.2.1 Behaviour

The activity and postural time budgets of the yearlings in each group of eight were recorded for 12 hours by instantaneous scan sampling (Martin and Bateson, 1993), over a four-day period on the second week of each rotation. Every fifteen minutes the behaviour, posture and location of each animal in the group was recorded (see appendix 1). During the first two-week period for each replicate (i.e. the first six weeks of the experiment) recordings were made between: 0800-1000, 1100-1300, 1400-1600, 1800-2000, 2200-0000, 0400-0600. During the second two-week period (i.e. the remaining six weeks of the experiment) observations were made between: 0600-0800, 1000-1200, 1300-1500, 1500-1700, 1900-2100, 2200-0000. Between each scan sample all animals in each group were observed continuously for five minutes per treatment and all instances of play and social (both agonistic and non-agonistic) behaviour (Martin and Bateson,

1993) as well as the identification of the individual involved was recorded (see appendix 2).

3.2.2 Limb lesions

The limbs of all animals were inspected for lesions at the start of the experiment. Thereafter all animals in each replicate were inspected at week eight and on the final week of the trial. Lesions were categorised as follows:

- Bare, hairless area
- Bare, red, hairless area or old scab
- Swelling not associated with heat or fluid i.e. bump
- Presence of blood i.e. wound and/or scab
- Open infected wound i.e. injury plus swelling
- Adventitious bursa i.e. fluid filled sac on knee or hock

3.2.3 Dirtiness scores of the out-wintering pad and animals

Once a week the out-wintering pad was scored using a scale of 1- 4, where 1= clean wood chips and 4 = wet faecal layer. Five areas (back, belly, legs front and rear and hind quarter) on all of the animals were scored at weeks four, eight and at the end of the trial, using a system adapted from Bergsten and Pettersson (1992). The sum of the four scores constituted the total dirtiness score:

1.0 Very good – clean, dry skin
2.0 Good – Some loose manure or wet spot
3.0 Quite dirty – partly dirty, or moist and dirty
4.0 Very dirty and/or very wet

3.2.4 Clinical illnesses

All clinical signs of illness/lameness were recorded and appropriate medical treatment provided where necessary, all veterinary treatment received was recorded.

3.2.5 Feed intake and sampling

All groups were fed by a diet feeder that facilitated weighing of the food delivered to the groups of eight on three consecutive days of the first week of each rotation (which started on Tuesday 23rd November). Intakes of the animals in the groups of eight were recorded by weighing any food leftover in the morning before fresh food was delivered. In addition a sample of the silage fed and the silage leftover was taken on each of the three days for composition analysis to determine the dry matter (DM) concentration (dried at 40 ^{o}C for 48 hours).

3.2.6 Chemical analysis of food

Samples of the feed offered, were analysed for crude protein (CP) and ash content. Samples from the silage pit and the concentrate were analysed for metabolizable energy (MJ/kg) (ME), samples from the silage pit were also analysed for *in-vitro* DM digestibility (DMD). These results were used to calculate the rate of heat production for each week feed intakes were recorded.

Table 1. The chemical composition of foods offered

	Silage	**Concentrate**
Metabolizable energy (MJ/kg DM)	10.18	12.091
Dry matter (DM) (g/kg)	284	865
Ash (g/kg DM)	63.7	63.96
Crude protein (g/kg DM)	134	184.33
In-vitro DM digestibility (g/kg DMD)	707	NA

NA-not available

3.2.7 Body condition score (BCS) and body weights

Body condition scores were recorded the week before housing and on the final week of the housing period on a scale of 1 to 5 as described by Wildman *et al.* (1982). At the same time all animals were weighed unfasted over two consecutive days.

3.2.8 Climatic recordings and climatic energy demand

Rainfall and solar radiation were measured over a 24-hour period at the weather station in Moorepark. Ambient air temperature, humidity and wind speed was recorded separately at both locations (outdoors/indoors) for three consecutive days on the first week of each rotation, using a hand-held Extech 34160 Hygro-Thermo-Anemomter. The recordings were taken at approximately 0900h, 1100h, 1300h and 1600h on those days.

CED (climatic energy demand) was estimated for all animals based on the model by Higgins and Dodd (1989) and adapted from Hickey et al. (2002):

CED=(Tb-Ta- (r.Rn.Ia)/(It+Ih+Ia) where CED=(W/m^2), Tb=core body temperature (^0C), Ta=air temperature (^0C), r=interception factor associated with radiation exchange (0.62), Rn=net radiation (W/m^2), Ia=environmental thermal resistance (km^2/W), It=tissue thermal resistance (km^2/W) and Ih=hair coat thermal resistance (km^2/W).

Heat energy (HE) was calculated from metabolisable energy (ME) intake and net energy required for gain using the equations based on the model by Higgins and Dodd (1989) and of the National Research Council (NRC, 1996). Heat of evaporation (he) was assumed to be 0.15 of HE. Body surface area was calculated from liveweight $^{0.67x}$0.09 (NRC, 1996). Net energy required for the gain achieved and for maintenance assuming no climatic energy demand was also calculated using the equations based on the model by Higgins and Dodd (1989). Body temperature of the eight animals in each group was measured by taking their rectal temperatures between 0800 and 1000 in the morning, and between 1500 and 1700 in the afternoon, using a Fortuna digital thermometer (IntraMed Ltd.).

At housing a sample of hair from the left hand side (LHS) of about 1mm in diameter was cut from the dorsal aspect of the transverse processes of the lumber vertebrae (L 4-6) immediately cranial to the coxal tubec of twenty-four heifers in each treatment. The same procedure was carried out at the end of the trial on the right hand side (RHS) of the same animals. The length of three hairs was measured using a callipers and the average of the three hairs was then used in the determination of the CED. CED calculations for the first half of the trail were conducted using the LHS hair lengths and for the second half of the trial the RHS hair lengths were used.

3.3 Statistical analysis

All data were analysed using the Statistical Analyses System (SAS, 1989). Data were tested for normality prior to analysis using the univariate procedure. The group mean (n=3/treatment) was the experimental unit in the analysis of the behaviour, feed intake and dirt scores. Data on the individual animal (n=24/treatment) was used in the analysis of average daily weight gains and body condition scores. The mean of the two, two week experimental periods was used in the analysis of the behaviour data. All of this data were non-parametric and were analysed by the Mann Whitney test using the NPAR1WAY procedure. Limb lesions were analysed by the Chi-square test using the frequency procedure. Feed intake, liveweight gain and body condition score data were analysed using the GLM procedure for a two by two factor randomised complete block design, with housing, nutrition, housing x nutrition and block in the model.

4. Results

4.1 Behaviour

4.1.1 Instantaneous scan samples

There was no effect of nutrition or housing on the proportion of observations of standing and lying (P>0.05) (Figure 1).

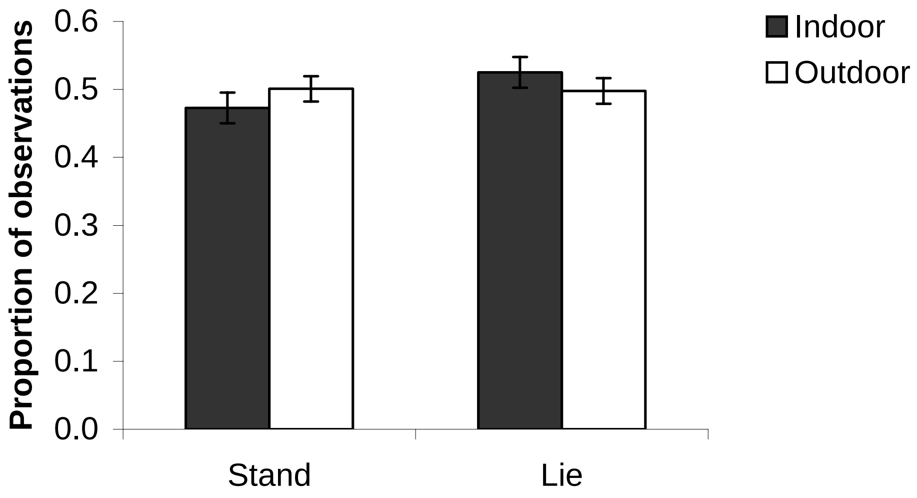


Figure 1. Proportion of observations of yearling heifers standing and lying in two housing treatments

There was no effect of nutrition or housing on the proportion of observations of ruminating, active, idling and sleeping behaviour (P>0.05). However, there was a tendency for outdoor yearlings to spend more time feeding than yearlings housed indoors (P=0.093) (Figure 2).

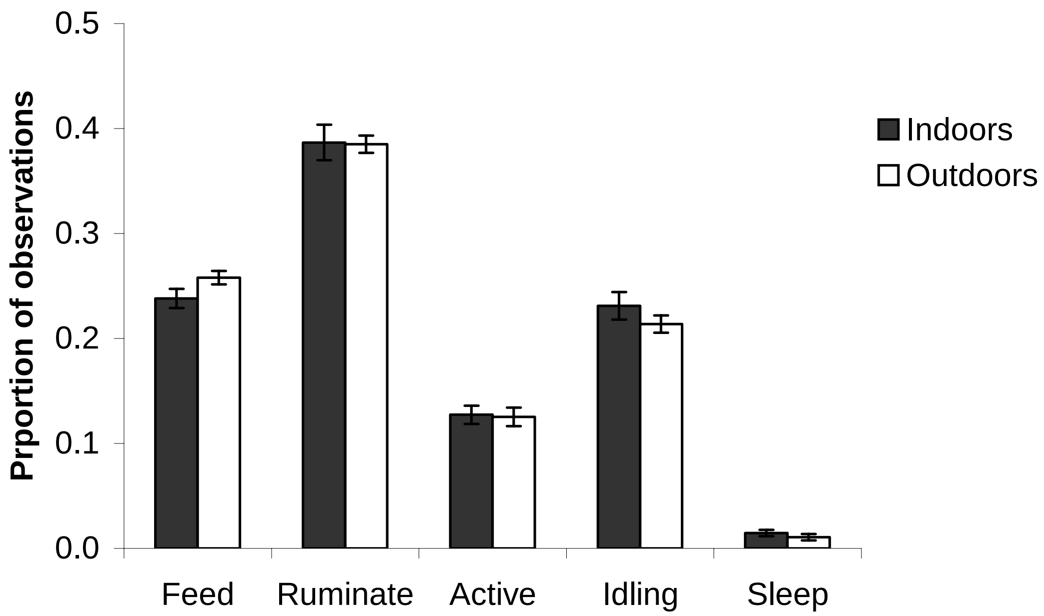


Figure 2. Proportion of observations of yearling heifers engaged in different behaviours in two housing treatments

There was no effect of nutrition on spatial behaviour (P>0.05). There was a significant effect of housing treatment on the proportion of observations of yearling heifers standing in the lying area (Figure 3). Outdoor yearlings spent significantly longer standing in the lying area than the indoor yearlings (P<0.05). There was a tendency for indoor yearlings to spend longer lying on the concrete area than the outdoor yearlings (P=0.090).

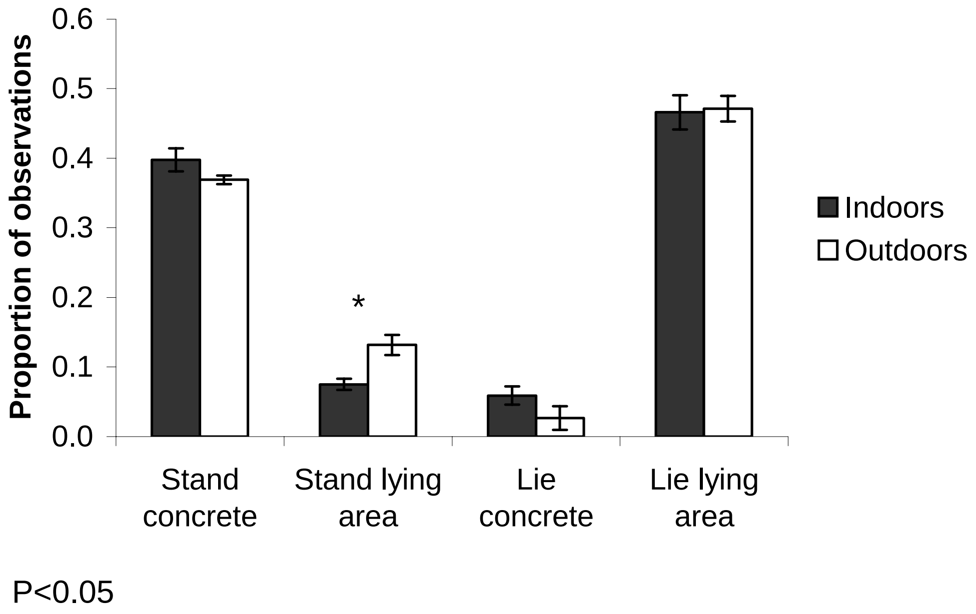


Figure 3. Effect of housing treatment on spatial behaviour of yearling heifers

4.1.2 Continuous recording, all-occurrence behaviour sampling

There was no effect of nutrition on the number of occurrences of trips, slips and falls (P>0.05). These behaviours were only recorded in indoors (Table 2). Significantly more trips and slips were recorded indoors (P<0.01) and there was a tendency for indoor yearlings to fall more than yearlings outdoors (P=0.074).

Table 2. Number of occurrences of trips, slips and falls recorded in both housing treatments

Behaviour	Indoors	Outdoors	P
Trip/slip	0.26±0.665	0	0.01
Fall	0.07±0.041	0	0.07

There was no effect of nutrition on the number of occurrences of comfort behaviour (P>0.05). A higher frequency of comfort behaviours was observed outdoors compared to indoors (P<0.01) (Table 3). A higher frequency of licking the costal arc, self grooming (P<0.01) and scratching with one leg raised (P<0.05) were observed outdoors. There was no effect of treatment on stretching and attempts to lick the costal arc (P>0.05).

Table 3. Number of occurrences of comfort behaviours recorded in both housing treatments

Behaviour	Indoors	Outdoors	P
Lick costal arc	0.73 ± 0.120	1.70 ± 0.177	0.01
Attempt to lick costal arc	0.01 ± 0.010	0.02 ± 0.013	NS
Scratch with leg	1.31 ± 0.135	2.38 ± 0.245	0.05
Stretch	0.22 ± 0.058	0.17 ± 0.55	NS
Self groom	3.80 ± 0.242	5.72 ± 0.415	0.01
Total number of comfort behaviours	8.67 ± 0.480	12.60 ± 0.584	0.01

NS-not significant

There was no effect of nutrition on the number of occurrences of social behaviour (P>0.05). There was a higher frequency of social grooming (P<0.01) and smelling (P<0.05) outdoors (Table 4). There was no effect of treatment on agonistic behaviours (P>0.05).

Table 4. Number of occurrences of social behaviours recorded in both housing treatments

Behaviour	Indoors	Outdoors	P
Groom another yearling	0.44 ± 0.076	0.98 ± 0.111	0.01
Smell another yearling	1.22 ± 0.106	2.35 ± 0.370	0.05
Agonistic (threat, butt, chase, displace)	1.31 ± 0.236	1.22 ± 0.116	NS

NS-not significant

There was no effect of nutrition on the number of occurrences of play behaviour (P>0.05). More incidences of play were recorded in outdoor animals than animals indoors (P<0.01) (Table 5). There was a higher frequency of head play, cantering and play chasing outdoors (P<0.01). Furthermore, more instances of individual play were recorded outdoors (P<0.001).

Table 5. Number of occurrences of play behaviour recorded in both housing treatments

Behaviour	Indoors	Outdoors	P
Head play	0.19 ± 0.056	0.72 ± 0.112	0.01
Canter	0.02 ± 0.013	0.21 ± 0.062	0.01
Individual play (buck, head toss, play bout)	0.22 ± 0.053	0.63 ± 0.136	0.001

Play chase	0.20 ± 0.059	0.75 ± 0.098	0.01

4.2 Health

4.2.1 Limb lesion scores

There was no effect of nutrition on the proportion of yearling heifers affected by different lesion categories (P>0.05). Significantly more yearlings indoors were affected by bare, hairless areas (P<0.05) (Table 6). Furthermore, more indoor yearlings had adventitious bursa than yearlings outdoors (P<0.001).

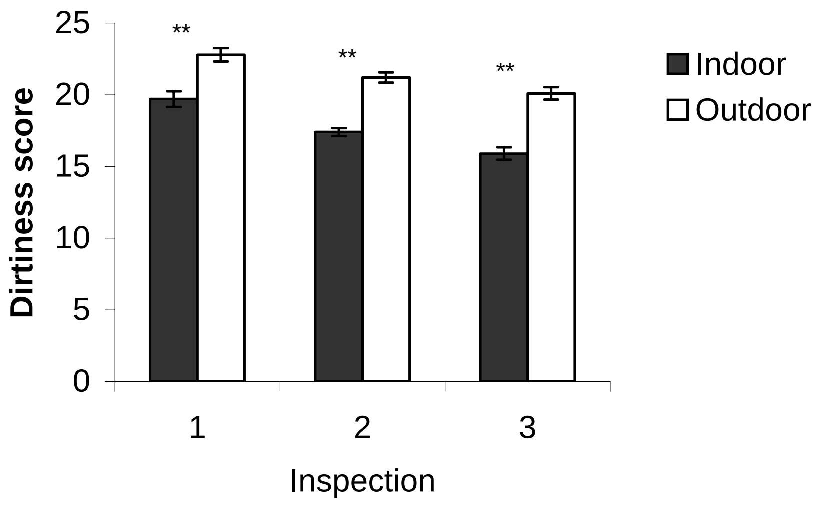
Table 6. Effect of two housing treatments on proportion of animals affected [% affected (number affected/number inspected)] by different types of lesion

Lesion	Indoor	Outdoor	P
Bare, hairless areas	15 (7/48)	0 (0/48)	0.05
Bare, red, hairless area or old scab	10 (5/48)	2 (1/48)	NS
Swelling not associated with heat or fluid	4 (2/48)	0 (0/48)	NS
Presence of blood and/or scab	10 (5/48)	2 (1/48)	NS
Open infected wound	0 (0/48)	0 (0/48)	NS
Adventitious bursa (fluid filled sac)	23 (11/48)	0 (0/48)	0.001
Lameness	2 (1/48)	0 (0/48)	NS

NS-not significant

4.2.2 Dirtiness scores

There was no effect of nutrition on dirtiness scores (P>0.05). However, there was a significant effect of housing treatment on dirtiness scores (Figure 4). Outdoor yearlings were significantly dirtier than those housed indoors (P<0.01) on all three inspection dates.



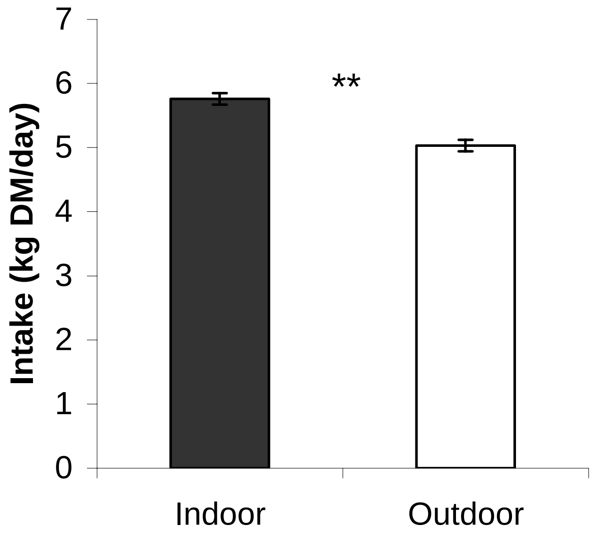
** P<0.01

Figure 4. Effect of two housing treatments on dirtiness scores of yearling heifers on three inspections

4.3 Production

4.3.1 Feed intake

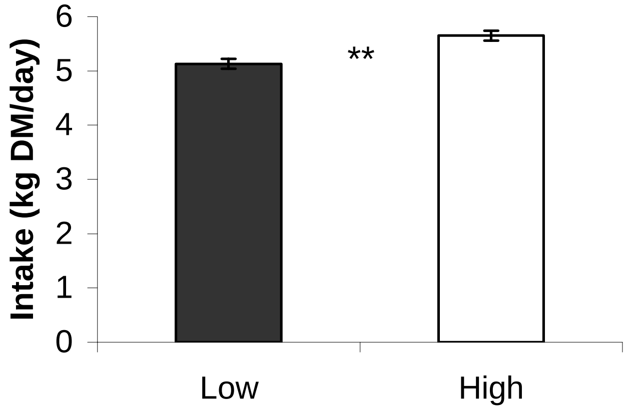
There was no interactive effect of treatment and nutritional level on the average daily dry matter intake (kg DM/day) per animal (P>0.05). There was a significant effect of housing (P<0.01) and a significant effect of nutrition (P<0.01). Outdoor yearlings had significantly lower intakes of feed than those indoors (P<0.01) (Figure 5).



** P<0.01

Figure 5. Effect of housing treatments on feed intake (kg DM/day)

Yearlings on the high nutrition diet had a significantly higher daily dry matter intake than yearlings on the low nutrition diet (P<0.01) (Figure 6).

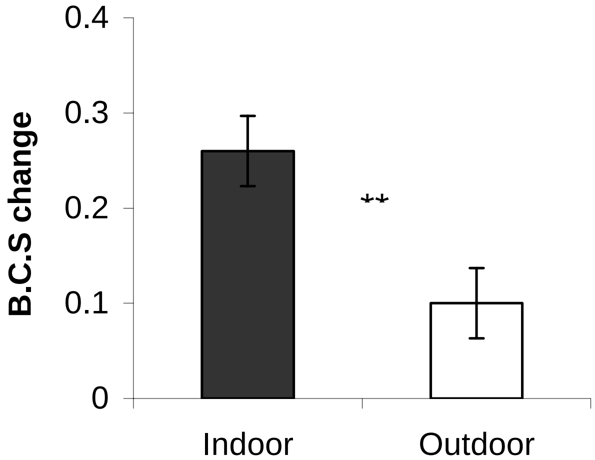


** P<0.01

Figure 6. Effect of nutrition on feed intake (kg DM/day)

4.3.2 Body condition score

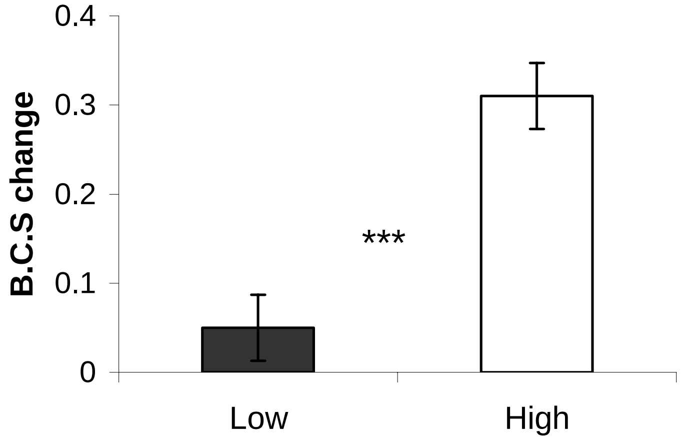
There was no interactive effect of treatment and nutritional level on body condition score change (P>0.05). There was a significant effect of housing (P<0.01) and nutrition (P<0.001). Animals accommodated on the out-wintering pad had a significantly lower body condition score change than animals housed indoors (P<0.01) (Figure 7).



** P<0.01

Figure 7. Effect of treatment on body condition score (B.C.S) change

High nutrition animals had a larger body condition score change than low nutrition animals (P<0.001) (Figure 8).

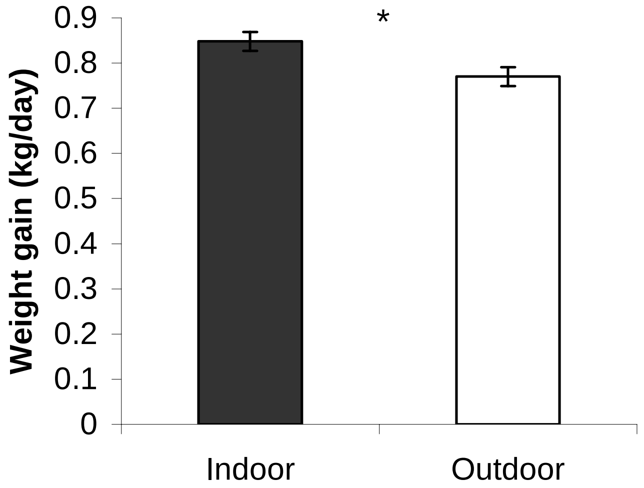


*** P<0.001

Figure 8. Effect of nutrition on body condition score (B.C.S) change

4.3.3 Average daily gain

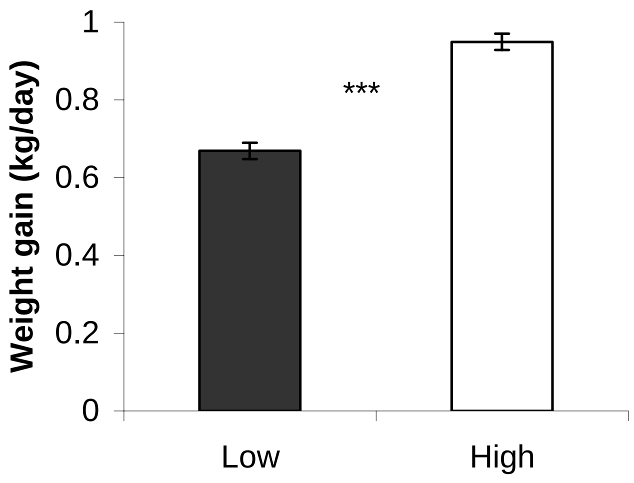
There was no interactive effect of treatment and nutritional level on average daily liveweight gain (kg per day) (P>0.05). There was a significant effect of housing (Figure 9). Animals accommodated on the out-wintering pad had significantly lower average daily weight gains compared to animals housed indoors (P<0.05).



P<0.05

Figure 9. Effect of housing treatment on average daily gain (kg per day)

There was a significant effect of nutrition on the average daily liveweight gain (Figure 10). Low nutrition animals had lower average daily gains than high nutrition animals (P<0.001).



*** P<0.001

Figure 10. Effect of nutrition on average daily gain (kg per day)

4.3.4 Energy efficiency

Yearlings in both outdoor treatments and indoors on the low nutrition diet had lower UFL intakes than what would be required to meet the daily liveweight gains they achieved (Table 7). Yearlings indoors on high nutrition gained 0.98 kg per day but consumed 0.17 UFL more than what would be recommended to achieve a daily liveweight gain of 1.0 kg.

Table 7. Average daily gain (ADG) kg per day, required (based on average liveweight of 260 kg [from O'Mara, 1993]) and actual energy efficiencies (UFL§ intake) and difference between required and actual UFL intake for heifers in four treatments

Treatments	**Outdoor low**	**Indoor low**	**Outdoor high**	**Indoor high**
ADG kg per day	0.62	0.72	0.92	0.98
Required UFL intake for growth rate achieved	4.27	4.52	5.01	5.27
Actual UFL intake	3.92	4.30	4.65	5.44
Difference (Required – Actual UFL intake)	-0.35	-0.22	-0.36	+0.17

§ feed unit for maintenance and lactation (Irish Republic)

4.4 Climatic recordings

Mean ambient air temperature was lower outdoors by 3 ^{o}C, while the humidity was higher indoors (Table 8).

Table 8. *Mean weather recordings (minimum - maximum) during the experimental period*

	Temperature *Mean °C (min-max)*	**Humidity** *Mean % (min-max)*	**Air velocity** *Mean km/h (min-max)*	**Rainfall** *Mean mm (min-max)*
Indoors	14.4 (6.5-19.1)	65.7 (46.7-84.2)	0	0
Outdoors	11.4 (0.5-13.7)	63.3 (45.0-100)	3.8 (0.0-12.7)	2.3 (0-11.6)

The climatic energy demand for yearlings outdoors was higher than that of yearlings indoors (Figure 11). The heat production of yearlings on the high nutrition diet was greater than that of animals on the low nutrition diet. Heat loss never exceeded heat production in any treatment on the days that weather recordings were made.

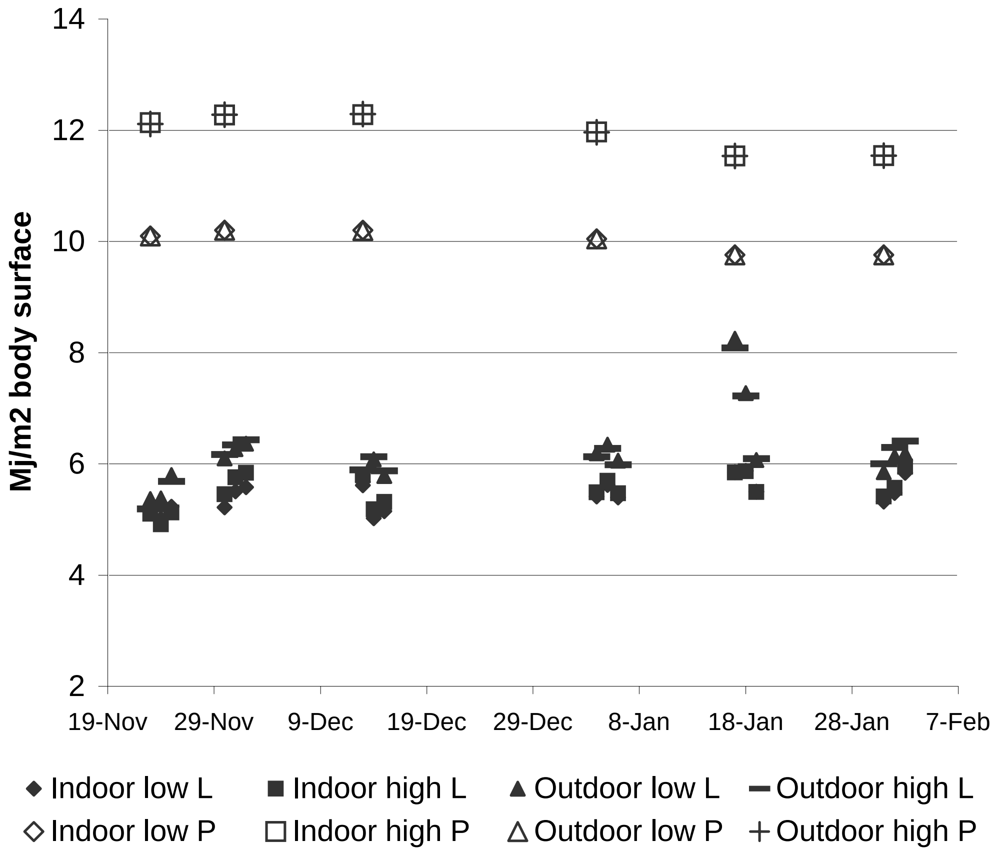


Figure 11. The effect of out-wintering on heat production (P) and heat loss (L)

5 Discussion

Information is limited on the effect of different housing systems on the welfare and performance of yearling dairy heifers. This is because most studies focused on heifer calves (e.g. Jensen *et al.*, 1998; Frankena *et al.*, 1992), pregnant heifers (e.g. Carson *et al.,* 2003; Redbo *et al.*, 2001) or older lactating cows (e.g. O'Connell *et al.,* 1989; Galindo *et al.,* 2000). Considering the importance of young replacement dairy animals in determining future production levels on a farm this study makes an important contribution to the literature on health and welfare effects of different housing systems.

According to some authors, an animal's comfort and welfare status is associated with the amount of time it spends lying down (Miller and Wood-Gush, 1991; Krohn *et al*., 1992; Winckler *et al*., 2003; Fisher *et al*., 2003). This study showed no difference in the proportion of time spent standing and lying between animals in cubicles or on an OWP. These results are in contrast to previous studies that found higher lying times for cows kept on pasture or on straw yards compared to animals housed indoors (Kerr and Wood-Gush, 1987; Singh *et al*., 1993; Philips and Schofield, 1994). In these studies it was suggested that the welfare of the animals that lay for longer was better than the animals that stood more. However, it is unlikely that the amount of time spent standing and lying has the same relevance for the welfare of young dairy animals as it does for cows.

Previous studies showed that cows prefer standing on bedded flooring to concrete flooring (Andreae and Smidt, 1982; Albright and Arave, 1997; Kiernan 2004). This is probably because of a reduced likelihood of slipping and falling and also alleviation of discomfort, often caused by concrete flooring. This is in accordance with the current study, where yearlings accommodated on the wood-chip pad were observed standing on the lying area more than those housed indoors in cubicles. The fact that these findings may have been influenced by the higher space allowance, since the amount of lying space available to yearlings outdoors was greater than that available indoors, and not the housing system *per se* is indisputable. Nevertheless, having a more yielding substrate underfoot could reduce the likelihood of lameness and alleviate discomfort (Singh *et al*., 1993; Vokey *et al*., 2001; Livesey *et al.*, 2002). Yearlings housed indoors also had a tendency to spend more time lying on the concrete area than yearlings outdoors. This could be explained by a reluctance to use the cubicles for some time even after the habituation period. According to O'Connell *et al.* (1993) cubicle refusal is a relatively common behavioural problem among young cattle introduced to cubicles for the first time.

The fact that there was no difference between treatments in the amount of time spent active as recorded by instantaneous scan sampling, but that there were marked differences between treatments in the number of behaviours recorded by all-occurrence behaviour sampling could be queried. The reason for this is likely that exploratory behaviour was not included in the ethogram of behaviours recorded by all-occurrence behaviour sampling but would have been recorded as active during instantaneous scan sampling. It was noted early in the trial that animals housed indoors tended to lick the fixtures and fittings a lot more than those housed on the out-wintering pad. And in hindsight this behaviour should have been recorded during the all occurrence behaviour sampling.

Today's intensive housing systems are associated with a number of behavioural problems, as they tend to restrict cattle's locomotion, exploratory and social activities (Hanninen *et al*., 2003). This was confirmed in the current study where animals indoors performed less social, comfort and play behaviours compared to those housed outdoors. According to some authors, the presence of play behaviour suggests good health and positive feelings, since activities included in play behaviour most often occur in healthy young animals (Dellmeier *et al.*, 1990; Fraser and Broom, 1997; Jensen *et al*., 1998; Jensen and Kyhn, 2000). Subsequently, its absence may be used as an indicator of reduced health and poor welfare status.

The occurrence of both individual and social play behaviours was higher among yearlings outdoors compared to those housed indoors. The presence of behaviours such as head play, canter and bucking observed outdoors are positive welfare indicator as both have physiological benefits with regard to physical strength and endurance (Fraser and Broom, 1997). Furthermore, play fighting develops social and cognitive skills necessary later in life (Fraser and Broom, 1997). These skills are of great importance to freshly calved heifers entering the milking herd for the first time. There are a number of reasons for a lower frequency of behavioural traits indoors. Firstly, a major constraint of intensive housing conditions is reduced space allowance due to high construction costs (Albright and Broom, 1997). This can have a negative effect on play behaviour especially in relation to locomotory play behaviours (Friend *et al*., 1985; O'Connell *et al*., 1989; Jensen *et al*., 1998; Albright and Arave, 1997; Jensen and Kyhn, 2000), like canter and play chase. According to Fraser and Broom, (1997) if an animal is confined and play is restricted, an outburst of play behaviour will usually be observed on release even among adults. Another major constraint that affected the level of play indoors was the concrete flooring. Concrete flooring forms a rough surface when first laid and provides a certain amount of grip. However due to mounted scrapers and animal traffic they become smooth over time and can result in higher incidences of slips and falls (Albright and Arave, 1997). According to Albright and Arave, (1997) cows are less likely to engage in certain behaviours as a result of an increased risk of slipping. Therefore, due to the unyielding surface indoors the yearlings were less likely to play chase, canter and buck. In contrast yearlings outdoors performed locomotory behaviours with confidence and without the risk of slipping, often involving two or more behaviours in sequence. Hence, it is reasonable to expect that environmental conditions effect the expression of play behaviour and the health status of an animal (Jensen *et al*., 1998) and can account for the differences found between treatments. Therefore, every effort should be made to optimise an animal's play, social and reproductive behaviours (Vitale *et al*., 1986) and performance without compromising their health, when considering alternative housing systems.

The frequency of comfort and social behaviours such as self and social grooming observed outdoors was also greater than that seen indoors. According to some authors another good indicator of the general health of cattle is their behaviour toward themselves and other members of the herd (Albright and Arave, 1997; Fraser and Broom, 1997; Keeling and Gonyou, 2001). Furthermore, social grooming strengthens the cohesiveness of groups of cattle (Albright and Arave, 1997), and allo-grooming in particular can reduce tension among con-specifics and stabilize social groups (Sato *et al*., 1993 cited by Keeling and Gonyou, 2001). Caudal licking is a useful behaviour in determining the quality of flooring in different housing systems as animals are in danger of slipping since they are in a unstable position with one hind leg lifted and a front leg positioned diagonally (Jungbluth *et al*., 2003). More frequent licking of the costal arc was observed in yearlings outdoors. This indicates that the footing of the animals indoors was not secure enough to allow them perform it comfortably. Jungbluth *et al.* (2003) observed that more caudal licking was performed when floors were covered with rubber mats. Hence, grooming behaviour in particular caudal licking and scratching with one leg raised may play a significant role when evaluating various flooring systems. According to Sainsbury (1986) appropriate housing conditions are essential in order for animals to perform maintenance behaviours such as self and social grooming and therefore, are important for good welfare (cited by Fraser and Broom, 1997).

The fact that limb lesions were only recorded in the animals indoors is probably a reflection of the higher frequency of trips, slips and falls recorded in this treatment. As has already been mentioned the higher frequency of such incidences can be attributed to the design and construction of the housing system, which in turn leads to physical injuries (Enevoldsen *et al*., 1994). The occurrence of an adventitious bursa or fluid filled sac on the knee was the most common and the most severe form of injury indoors although one case of lameness was also recorded. Adventitious bursa arise in soft tissue areas, particularly over bony prominences such as the hock and knee, as a result of either trauma or repeated subjections to stresses. Such physical injuries are the cause of much pain among farm animals and are therefore are a major welfare concern (Webster, 1997). The physical environment such as poor cubicle design and hard, wet slippery concrete flooring are major factors predisposing cattle to such injuries (Webster, 1997), since there is an increased risk of slipping and falling and therefore causing trauma to the joints. Although bare, hairless patches are not as serious a health issue they also indicate traumatic contact with housing fixtures and fittings and a higher incidence of these injuries was also recorded among yearlings indoors. Therefore, it can be concluded that the presence of limb lesions and the indoor environment were intrinsically linked (Rushen *et al.*, 1998; Haley *et al.,* 1999). Furthermore, that the animals on the out-wintering pad suffered less and thus had improved welfare. It is worth mentioning that although foot lesions were not scored in this study calves housed on straw beds have a lower incidence of sole haemorrhages compared to calves housed on slatted concrete floors (Frankena *et al.*, 1992). Thus, it is likely that the outdoor yearlings would also have had superior hoof health to the animals indoors. Such physical injuries may have implications for an animal's longevity and it is possible that performance at a latter stage may also be affected. Physical injury is considered an important indicator of animal health along with having a negative effect on production (Enevoldsen *et al*., 1994). Therefore, it is important to consider welfare in the design and management of systems, with special regard to flooring. This study provides useful information for a better understanding of the multifactoral relationships between the behaviour and health problems associated with the two housing systems for young dairy cattle.

All the animals were very dirty at the start of the experiment. This can be explained by the fact that all yearlings were housed indoors on slatted floors for two weeks, prior to the experiment because of adverse weather conditions. This resulted in their coats becoming heavily soiled since they were not used to the housing system and refused to lie in the cubicles. However, the yearlings outdoors were consistently dirtier than their counterparts indoors throughout the experiment. This is in accordance with Kiernan (2004) who also found higher dirtiness scores in pregnant heifers kept on an out-wintering pad compared to those indoors in cubicles. The cleanliness of animals depends largely on the amount of space available and how often the area is cleaned and the type of surface on which they are housed (Fisher *et al*., 2003; Scott and Kelly, 1989; Hickey *et al*., 2002). During the course of the experiment the pad was cleaned off once mid way through the experiment, thereafter the weather was relatively dry, the dirt score of the pad remained relatively low and the animal's dirt score also declined.

Another factor, which can influences an animal's cleanliness is the hair coat length. According to Scott and Kelly (1989) animals with longer hair are dirtier than those with shorter hair. The authors of this paper found that animals maintained outdoors had longer hair coat length, which was probably a result of a higher climatic energy demand. This could have contributed to the increased dirtiness scores of yearlings on the out-wintering pad. Furthermore, it was observed that the animals housed indoors began to shed their coat soon after housing probably in response to a lower climatic energy demand, which resulted in much of the soiled coat falling off.

Lower feed intakes were recorded outdoors. Wet weather conditions may have reduced the quality, and palatability of the silage outdoors (Redbo *et al.*, 1996; Albright and Arave, 1997). Secondly, although animals in all treatments could feed simultaneously the yearlings housed indoors were able to access their feed with greater ease compared to yearlings outdoors owing to a slight difference in the design of the feed face. As a consequence of a lower average daily feed intake by the yearling heifers outdoors they experienced a reduction in average daily gain relative to the yearlings housed indoors. This was also reflected in their body condition scores. Kiernan (2004) also found a reduction in liveweight gain of pregnant heifers housed outdoors compared to heifers indoors in cubicles. However, these findings and the findings of the current study are in contrast to previous studies, where no negative effect was found on overall growth rate of animals housed outdoors during the winter period (McCarrick and Drennan, 1972; Redbo *et al*., 1996; Hickey *et al*., 2002). Nevertheless, yearlings outdoors on the low and high nutrition diets achieved daily liveweight gains of 0.62 and 0.92 kg respectively with intakes of 3.92 UFL and 4.65 UFL respectively, both of which were just over 0.3 UFL lower than that required to achieve such growth rates (O'Mara, 1993). In contrast, animals indoors on the high nutrition diet achieved an ADG of 0.98 kg with intakes of 5.44 UFL which was higher than that recommended in order to gain 1.0 kg per day. Therefore, it can be concluded that although yearlings outdoors had a lower energy intake they used their feed more efficiently than the animals indoors. Further research is required to elucidate the reasons for this. However, it is likely that it was the improvements to animal health and comfort on the OWP that were responsible for the improvements in performance (French and Hickey, 2005). These authors showed that improvements in the performance of beef cattle on OWPs were due to the higher space allowance and softer underfoot conditions inherent to the OWP, and not to the outdoor environment *per se.*

Finally, it is worth mentioning that the ADG of the yearlings in three of the treatments was above the 0.6 to 0.7 kg per day target weight gain recommended for yearling heifers by the Teagasc advisory service (cited by Fitzgerald, 2002). This could be because the quality of the silage fed (71 % DMD) was well above the countries average of 67% DMD (Fitzgerald, 2002). Even the animals on the low nutrition diet outdoors were well within the recommendations, with an average daily gain of 0.67 kg. This is probably because the yearlings outdoors did not experience cold stress at any point during the experimental period.

6 Conclusions

In conclusion, the out-wintering pad was associated with improvements to animal health and behaviour. Furthermore, the system did not compromise animal performance. It is likely that these differences were driven more by the higher space allowances and better underfoot conditions associated with the OWP than to the outdoor environment *per se.*

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Appendix 1

Ethogram for recordings of yearling behaviour by instantaneous scan sampling

Behaviour	Definition
Posture	
Stand	
Stand hunched	Stand with back hunched (outdoors only)
Stand concrete	Indoors-passageway between cubicles, outdoors-concrete feeding area
Stand lying area	Indoors-cubicle, outdoors-wood-chip area
Stand half in cubicles (included in Stand lying area for indoor animals)	Two front legs in cubicle and two back legs on the passageway
Lateral lying	Lying on side with all legs stretched out fully
Ventral with head back against the body	Head tucked into the flank, normal position for sleeping
Ventral with head resting in front of yearling	Head resting in front on the ground
Ventral with head upright	Normal position for ruminating while lying
Behaviour	
Feeding	
Ruminating	
Sleeping	With eyes closed
Idling	Doing nothing but awake (standing/lying)
Active	Doing anything except the above, includes allo-grooming, self grooming, being groomed, grooming another, exploration, walking/running, getting up/lying down, engaged in agonistic or play behaviour
Location	
Feed face	
Trough	Water source
Lying area	Indoors-cubicle, outdoors-wood-chip pad
Concrete area	Indoors-passageway & feed face, outdoors-feed face

Appendix 2

Ethogram for continuous recordings of yearling behaviour

Behaviour	Definition
Comfort	
Stretch	
Lick costal arc	Stand with one hind leg lifted and a front leg positioned diagonally while licking the costal arc
Attempt to lick costal arc	Definite attempt but does not succeed
Scratch off house, fixture or fitting	Rub part of body off house, fixture or fitting while standing
Scratch off another yearling	
Self groom	Lick part of body while standing or lying
Scratch with leg	Stand, scratch part of body with one leg rasied
Social	
2a. Agonistic	
Threat	Head lowered, back may be arched
Butt	Directs blow with forehead towards another yearling
Chase	
Displace	Displaced from lying area or feed face
2b. Non-agonistic	
Allo-groom	Two yearlings grooming each other while standing
Groom another	One yearling grooms another while lying or standing
Smell another yearling	
Nuzzle udder	
2c. Play	
Head play	Face to face contact associated with pushing and rubbing
Play chase	One yearling chases another, may involve bucking
Buck	Two back legs kick up
Canter	Moving forward in a quick session
Head toss	
Play bout	Involves two or more play behaviours being performed together
2d. Sexual	
Mount	Either full mount or rest head on hindquarters of another yearling
3. Other	
Trip/stumble	Trip/stumble but not fall
Trip/stumble & fall	
Slip	Slip but not fall
Slip & fall	