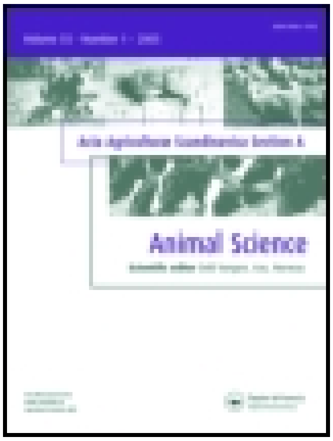

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Different housing systems for growing dairy bulls in Northern Finland - effects on performance, behaviour and immune status

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ORIGINAL ARTICLE

Different housing systems for growing dairy bulls in Northern Finland – effects on performance, behaviour and immune status

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Abstract

We compared performance, behaviour and immune status of Ayrshire bulls raised in different housing environments in Northern Finland. Thirty bulls were allotted to one of three treatments: uninsulated barn (UB bulls, five animals/pen, two pens), forest paddock (PAD bulls, five animals/PAD, two PADs) and tie-stall in an insulated barn (IB bulls, 10 animals in individual stalls). The daily gain tended to be higher in the IB bulls than in the PAD bulls. Energy intake of the UB and PAD bulls was higher but the feed conversion rate was worse than that of the IB bulls. The time budgets and diurnal rhythms of the UB and PAD bulls were quite similar. The measures of immune (IgG) status indicate that the hygiene of the bulls' surroundings decreased in summer, especially in the IB. Our study indicates that dairy bulls can be overwintered outdoors in Northern Finland without warm housing facilities.

Keywords: *Beef production, feed intake, gain, outdoor housing, uninsulated housing.*

Introduction

During the last decade, European agricultural policy reforms have resulted in great changes on the beef sector (Pihamaa & Pietola, 2002). In a high-cost country, such as Finland, these reforms have important implications for the economics of the beef sector and for farmers' incentives to rear cattle. Therefore, in order to maintain the profitability in beef production, many beef producers have been investing in larger production units (Jalonoja et al., 2004). Production costs can be reduced also by using simple housing solutions and, therefore, year-round outdoor housing of growing cattle in uninsulated buildings or in extensive forested lands has become increasingly more common in Finland. For example, in Taivalkoski, north-eastern part of Finland (latitude 65°N), 400–600 growing cattle from 25 to 30 dairy farms are raised every year on extensive forested land (0.5 animal unit/ha) (Uusi-Kämppä et al., 2007). This makes it possible to increase the number of animals on small family farms without expensive investments in new housing facilities. These farms have insulated buildings (typically tie-stalls) for dairy cows, but young cattle (bulls and heifers) are raised year-round on forested land. Hands-on experiences in the Taivalkoski area indicate that young cattle perform quite well outdoors if the animals are carefully managed (Lehtiniemi et al., 2001).

In general, growing cattle are very cold-hardy and have very low critical temperatures (Webster, 1974; Young, 1981). For example, beef cattle weighing 350 kg with a weight gain of 1.3 kg per day have a lower critical temperature of −26°C in conditions of very low air movement (Webster, 1974). In previous studies, growing cattle often exhibited good performance in outdoor or uninsulated conditions (Mossberg et al., 1992, 1993; Redbo et al., 1996; Huuskonen et al., 2009), but these studies were mainly conducted in latitudes further south than Northern Finland. In Finland, the effect of uninsulated housing has been studied mainly with good results with dairy calves (Kauppinen, 2000;

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Hänninen et al., 2003; Hepola et al., 2006), beef heifers (Manninen et al., 2007) and suckler cows (Manninen et al., 2008). However, these Finnish experiments were also conducted in latitudes further south than Northern Finland, e.g. in Viikki (latitude 60°N) and Tohmajärvi (latitude 62°N).

In low temperatures, cattle are able to maintain a relatively constant body core temperature and thermal balance via anatomical, physiological, biochemical and behavioural coping mechanisms (Webster, 1974; Young, 1981, 1983; Kauppinen, 2000). Huuskonen et al. (2009) concluded that finishing Hereford bulls can be overwintered outdoors in Northern Finland without warm housing facilities. However, there is only little scientific knowledge on the effect of cold in the performance and behaviour of growing dairy bulls under uninsulated housing environments. Furthermore, there is a lot of public concern about the welfare of these outdoor housed animals even though Finnish animal protection regulations (Ministry of Agriculture and Forestry, 2002) have been imposed aiming at minimising risks of harsh winter conditions for cattle welfare. In year-round outdoor housing, for example, the animals must have access to unfrozen water and bedded lying area inside a shelter, and unacclimatised animals are not allowed to be transferred from inside to outdoor housing during the cold time of the year.

The objective of the present study was to determine the performance and immune status of growing dairy bulls housed in an insulated tie-stall (IB), an uninsulated barn (UB) and in a forest paddock (PAD) in Northern Finland**.** Immune status of the bulls was determined because it can be used as an index for long-term stress and disease susceptibility (Broom & Johnson, 1993). The behaviour of the bulls housed in the UB and forest PADs was also studied.

Materials and methods

The experiment was conducted at the North Ostrobothnia Research Station of MTT Agrifood Research Finland in Ruukki (64°44′N, 25°15′E), from November 2000 to December 2001. The experimental procedures were evaluated and approved by the Animal Care and Use Committee of MTT Agrifood Research Finland.

Animals and pre-experimental period

Thirty Finnish Ayrshire bull calves were purchased from local dairy farms when they were 44 ± 8 kg live weight (LW, mean $\pm$ SD) and 14 ± 5 days old. During the pre-experimental period from June 2000 to November 2000, the calves were housed in an UB in partly straw-bedded pens (five calves in each pen, 3.2 m^2 per calf). The calves were dehorned at the age of three weeks. During the pre-weaning period (from 0.5 to 2.5 months old) they received milk replacer (15.8 MJ metabolisable energy (ME)/kg dry matter (DM): delivered by Valio Ltd., P.O. Box 10, FI-00039 Valio, Finland), grass silage and a commercial pelleted calf starter (12.3 MJ ME/kg DM) produced by Raisio Nutrition Ltd. (P.O. Box 101, FI-21201 Raisio, Finland). The average dry matter intake (DMI) during the pre-weaning period was 1.19 kg/d and the average ME intake 16.3 MJ/d. During the post-weaning period (from 2.5 to 5.4 months old) the calves received grass silage and concentrates (commercial pelleted calf starter, barley and rapeseed meal). The average DMI was 3.91 kg/d and ME intake 47.3 MJ/d during this post-weaning period. The calves had free access to water for the whole time. The animals grew normally: the average live-weight gain (LWG) of the calves was 677 g/d during the pre-weaning period and 1250 g/d during the post-weaning period. Two animals were lost due to pneumonia during the pre-experimental period, and to replace the lost animals, another two calves were purchased from local dairy farms in November 2000.

Experimental design

At the beginning of the experiment in November 2000, when the bulls were 5.4 ± 0.8 months old, the bulls were divided into six groups of five animals balanced according to LW. These groups were randomly allotted to one of three treatments: UB (UB bulls, five animals/pen, two pens), forest PAD (PAD bulls, five animals/PAD, two PADs) and IB (IB bulls, 10 animals in individual tie-stalls). The experiment ended in December 2001 at slaughter, when the bulls were 18.6 ± 0.8 months old. One PAD bull and one IB bull were lost during the experiment, i.e. there were 28 bulls left at the end of the experiment. In regard to performance data, the experiment was divided into three sub-experimental periods: first winter (1 November 2000 to 18 April 2001), summer (19 April 2001 to 3 October 2001) and second winter (4 October 2001 to 9 December 2001).

Housing environments

The UB bulls were placed in an UB into adjacent pens (4×8 m). In the pens, the space allowance was 6.4 m^2 per bull, which was 2.4 m^2 per bull more than the minimum recommended space allowance for the cattle over 500 kg LW in this type of housing in Finland (Ministry of Agriculture and Forestry, 1997). Very crowded conditions were avoided in our study due to their well-known harmful effects on the welfare of growing cattle (e.g. Ruis-Heutinck et al., 2000). The UB was covered with a roof and it had solid wooden walls on all sides except on the front side that was left open. The rear half of the pen area was a straw-bedded lying area, and the fore half was the feeding area with a solid concrete floor. A feeding trough was situated on the front side of the pen, and there was 0.8 m feeding space per bull at the feeding trough. There was one heated water bowl between the pens offering water for all ten UB bulls. The concrete feeding area was cleaned three times a week and the bedded lying area was cleaned monthly. Fresh straw was added in the bedded lying area three times a week.

The PAD bulls were placed into adjacent forest PADs (50×100 m, 1000 m^2 per bull) that were built up in a young forest. The vegetation of the PAD area consisted mostly of young conifer trees mixed with some birches. The ground was covered with twigs and grass. The vegetation and soil texture of the PAD area have been described in detail by Uusi-Kämppä et al. (2007). Between the adjacent PADs a wooden fence separated them from each other. The other three sides of the PADs were fenced with an electric fence.

Between the two PADs there was a simple, roofed, three-walled shed (8×4 m) available for the bulls. The floor of this shed was deep straw-bedded. In front of the shed there was a feeding area (8×4 m) with a solid concrete floor. The shed as well as the feeding area were split into two with wooden walls so that each group of PAD bulls had access to a shed area of 4×4 m and a feeding area of 4×4 m. In front of the feeding area there was a feeding trough providing a feeding space of 0.8 m per bull. There was one heated water bowl in the feeding area offering water for all ten PAD bulls. The concrete-floored feeding area was cleaned twice a week. Fresh straw was added in the bedded lying area three times a week in winter and once a week during summer. The bedding was removed once during the experiment. The year preceding this experiment, 10 bulls of Hereford breed had been housed in this same PAD area, which had caused some damage and wear to the vegetation and ground of the PAD (Uusi-Kämppä et al., 2007; Tuomisto et al., 2008).

The IB bulls were placed in an IB in adjacent tie-stalls. The width of the stalls was 70–90 cm for the first six months and 113 cm until the end of the experiment. The bulls were tied with a collar around the neck, and a 50 cm long chain was attached to a horizontal bar 40–55 cm above the floor. The floor surface was solid concrete under the forelegs and metal grids under the hind legs. No bedding was used in the floor. All bulls had their own water bowls. Daily outdoor and indoor temperatures and daily rainfall were measured at the experimental site in Ruukki throughout the experiment.

Feeding and feed analyses

All bulls were fed *ad libitum* with total mixed ration (TMR) three times in a day (approximately at 7:00 hours, 12:00 hours and 18:00 hours). Refused feed was collected and measured at 7:00 hours daily. The IB bulls were fed individually, whereas the UB and PAD bulls were fed groupwise on a pen level. The DM of the TMR consisted of grass silage (600 g/kg DM) and rolled barley (400 g/kg DM). The daily ration also included 150 g of a mineral mixture (Tähkä Apekivennäinen: Ca 235, P 8, Na 74, Mg 40 g/kg: delivered by Feedmix Ltd., Koskenkorva, Finland). A vitamin mixture (Xylitol ADE-Vita: A 2,000,000 IU/kg, D_3 400,000 IU/kg, E DL-α-tocopheryl acetate 1000 mg/kg, E DL-α-tocopheryl 900 mg/kg, Se 10 mg/kg: delivered by Suomen Rehu Ltd., Espoo, Finland) was given weekly at 50 g/animal. No medications were used in any of the feeds. The grass silage was primary growth from a timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) sward and ensiled in bunker silos with a formic acid-based additive (AIV-2 Plus: 760 g formic acid/kg, 55 g ammoniumformiate/kg: delivered by Kemira Ltd., Oulu, Finland) applied at a rate of 5 l per t of fresh grass.

Grass silage was analysed for DM (determined at 105°C for 20 hours) at the beginning of the experiment and twice a week thereafter for preparation of TMR. Silage sub-samples for chemical analyses were taken twice a week, pooled over periods of four weeks and stored at −20°C. Thawed samples were analysed for DM, ash, crude protein (CP), neutral detergent fibre (NDF), silage fermentation quality (pH, water-soluble carbohydrates, lactic and formic acids, volatile fatty acids, soluble and ammonia N content of total N) and digestible organic matter (DOM) in DM (D value). Concentrate sub-samples were collected weekly, pooled over periods of four weeks and analysed for DM, ash, CP and NDF. The analyses were made as described by Huuskonen et al. (2007a,b). The ME value of the feeds was calculated as described by Huuskonen et al. (2007a,b, 2008). The digestibility coefficients of barley were taken from Finnish feed tables (MTT, 2006). The supply of amino acids absorbed from the small intestine (AAT) was calculated according to Finnish feed tables (MTT, 2006).

Live weight (LW) and carcass measurements

The animals were weighed on two consecutive days at the beginning of the experiment and thereafter every 28 days until the end of the experiment when they were weighed on two consecutive days before slaughter. The target for average carcass weight in the experiment was 310 kg. The LWG was calculated as the difference between initial and final LW. After slaughter in a commercial meat plant carcasses were weighed hot. Cold carcass weight was estimated as 0.98 of hot carcass weight. Dressing proportions were calculated from the ratio of cold carcass weight to final LW. Carcass conformation and carcass fatness were determined according to the EUROP (E: excellent, U: very good, R: good, O: fair, P: poor) classification (Commission of the European Communities, 1982). For conformation, development of carcass profiles, in particular the essential parts (round, back, shoulder), was taken into consideration according to the EUROP classification. Each level of conformation scale was subdivided into three sub-classes (e.g. O+, O, O −) to a transformed scale ranging from 1 to 15, 15 being the best conformation. For fatness, the amount of fat on the outside of the carcass and in the thoracic cavity was taken into account using a classification range from 1 to 5 (1: low, 2: slight, 3: average, 4: high, 5: very high).

Table I. Classification and description of postures and activities of bulls recorded during behavioural observations.

Behaviour	Description
Lying totally	The bull is lying in any position with trunk in contact with the ground.
Lying on bedded lying area	The bull is lying on the bedded lying area on the rear half of the pen in the uninsulated barn or inside the shelter in the paddocks.
Lying on concrete floored feeding area	The bull is lying on the concrete floored feeding area.
Lying on forest area	The PAD bull is lying on the forest area.
Totally on forest area	The PAD bulls is lying or standing on the forest area.
Eating TMR	The bull is eating and masticating feed mixture at the feeding trough.
Grazing and browsing	The PAD bull is taking bites and masticating grass, branches, twigs, etc. in the forest.
Ruminating	The bull is chewing cud in any position.
Self-grooming	The bull is licking own body or rubbing it against any equipment or trees.
Social behaviour	The bull is performing social behaviour e.g. social licking, butting or sexual behaviour.
Walking	The bull is walking without any other activity except observing or sniffing the environment.
Other behaviours	All behaviours that did not fit in any above activity category, e.g. the bull is drinking or idling.
Shivering	The bull's body is trembling strongly.

Behavioural observations of the uninsulated barn (UB) and paddock (PAD) bulls

The behaviour of the bulls housed in the UB and forest PADs was observed in February and July for 24 hours each month. In February, 40 W light bulbs were placed above the bedded lying areas to allow night time observation. The PAD bulls were not observed to spend time out of reach of the lights during the dark hours. At the outset of the behavioural observations the bulls were approximately 8.2 ± 0.9 and 13.7 ± 0.9 months old and weighed approximately 260 ± 21 and 447 ± 41 kg in February and July, respectively. During the observations, the maximum temperatures were $+5.5$ and $+26.7$°C, minimum temperatures -25.0 and $+9.4$°C and mean temperatures -11.0 and $+17.5$°C in February and July, respectively.

The bulls were observed directly using instantaneous sampling with a five-minute sampling interval (Martin & Bateson, 1993). At each sample point, each bull was scanned and the posture and activity of the bull were registered according to a classification presented in Table I. Both groups of the UB bulls were observed simultaneously, whereas the two PAD groups were observed separately mainly because of the larger area in the PADs. At night both PAD groups were observed simultaneously, because the bulls were situated close to the shelter. At other times, when the PAD bulls were moving on a larger area, the groups were observed separately. Observations were made in sessions of 2–4 hours on consecutive days to cover the whole 24 hours. There were a total of 6–8 observation sessions per group for 24 hour period. In February, the observations were made from a tractor placed in front of the UB or the PADs. In July, the observations were made from a 2.5 m high tower placed in front of the UB or the PADs. In the PADs, the observations were carried out with the aid of binoculars.

Measurement of immune status

At the end of the behavioural observation period in February and July, blood samples were collected from the UB, PAD and IB bulls. Immune status of the bulls was estimated by determining serum total IgG concentration. Blood samples were collected in the morning before feeding into 9 ml tubes (Vacuette) by jugular venopuncture using 20G needles. After centrifugation, 1 ml of serum was pipetted from each sample into three tubes, stored first at $-12°C$ and then at $-70°C$, until assayed. The serum samples were assayed with an enzyme-linked immunosorbent assay (ELISA) (Varley et al., 1985) modified for bovine IgG determination (Morrow-Tesch & Jones, 1997).

Statistical analyses

The statistical analyses of the performance data were performed using the SAS general linear models procedure (SAS Institute Inc., Cary, NC, USA). Daily feed intake was measured separately for each pen (i.e. intake for five bulls) in the UB and in the forest PAD. In the IB the bulls were individually fed. However, a group of five bulls was used as an experimental unit in the IB, too, and thus there were two experimental units per housing environment. Feed and energy intake data were analysed using one-way analysis of variance with the following statistical model (1):

$$Y_{ik} = \mu + \beta_{ik} + \varepsilon_{ik} \tag{1}$$

where $i = 1, 2, 3$ (housing environment), $k = 1, 2$ (two groups per housing environment). Y_{ik} is the dependent variable of the kth group in the ith housing environment. μ is the general mean and β_i is the effect of the ith housing environment. Furthermore ε_{ik} is the residual error.

The rest of the performance variables (i.e. LW, carcass weight, LWG, dressing proportion, carcass conformation and carcass fat score) were measured individually and analysed using the general linear models procedure. The following statistical model (2) was used to analyse the performance data:

$$Y_{ijk} = \mu + \beta_i + \theta_{j(i)} + \varepsilon_{ijk} \tag{2}$$

where $i = 1, 2, 3$ (housing environment), $j = 1, 2$ (two groups per housing environment), $k = 1, 2, 3, 4, 5$ (four or five animals per group). Y_{ijk} is the dependent variable of the kth animal in the ith housing environment and the jth group in the housing environment. μ is the general mean and β_i is the effect of the ith housing environment. Furthermore, $\kappa_{j(i)}$ is the effect of the jth group nested in the ith housing environment and ε_{ijk} is the residual error. Normality of residuals was checked for each analysis using graphical methods: box-plot and scatter plot of residuals and fitted values. Differences between the housing environments were compared using an *a priori* test (Dunnett's test) so that IB was used as a control environment and comparison of the environments was based on IB.

The statistical analyses of the behavioural and immune status data were performed with SPSS for Windows 14.0 (SPSS, Inc., Chicago, IL, USA) using a linear mixed model procedure. The group of five bulls was used as the experimental unit. The linear mixed model (3) for the behavioural and immune status data used was:

$$Y_{ijkl} = \mu + \beta_i + \gamma_j + \beta\gamma_{ij} + \theta_{k(i)} + \varepsilon_{ijkl} \tag{3}$$

where $i = 1, 2, 3$ (housing environment), $j = 1, 2$ (season), $k = 1, 2$ (two groups per housing environment), $l = 1, 2, 3, 4, 5$ (four or five animals per group). Y_{ijkl} is the dependent variable of the lth animal in the ith housing environment, the jth season and the kth group in the housing environment. μ is the general mean, β_i is the effect of the ith housing environment, γ_j is the effect of the jth season and $\beta\gamma_{ij}$ is the effect of interaction between the ith housing environment and the jth season. Furthermore, $\kappa_{k(i)}$ is the random effect of the kth group nested in the ith housing environment. Finally, ε_{ijkl} is the residual error. The covariance matrix for repeated measurements was selected using Akaike's information criteria. Compound symmetry structure and heterogeneous compound symmetry structure were used. Normality of residuals was checked for each analysis using graphical methods: box-plot and scatter plot of residuals and fitted values. If needed, the variable (x) was natural logarithm ($x+1$) transformed. In immune status analyses, pairwise comparisons between the housing environments were carried out using the Bonferroni correction of the P-values.

Diurnal rhythms of the UB and PAD bulls are illustrated for winter and summer. In order to simplify this illustration, the original behavioural classes were pooled to three larger behavioural categories. The lying category included lying in any position, the eating category chewing and masticating TMR at the feeding trough and the other behaviours category any behaviour performed in standing position excluding eating TMR.

Results

Climatic data

The air temperature of the IB varied between 5 and 15°C in winter (October–April) and between 15 and 25°C in summer (May–September). Daily outdoor temperatures and daily rainfall during the experiment are presented in Figures 1 and 2, respectively.

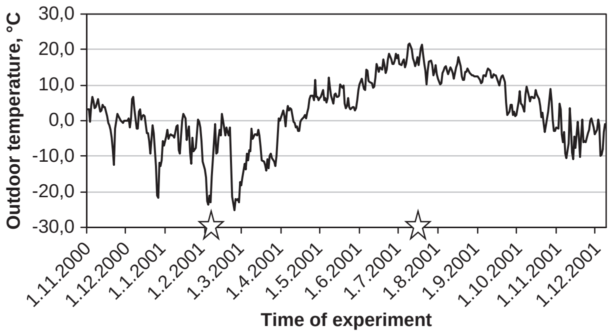

Figure 1. Mean daily outdoor temperatures during the experiment. Behavioural observation periods in February and July are indicated by asterisks.

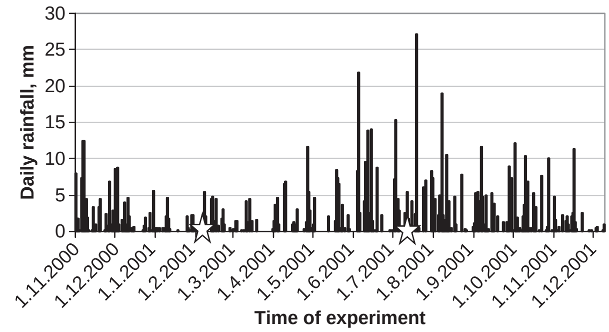

Figure 2. Daily rainfall during the experiment. Behavioural observation periods in February and July are indicated by asterisks.

Feeds and animal performance

The content of DM, organic matter (OM), CP, NDF and calculated contents of ME and AAT of the grass silage, barley and TMR used are given in Table II. The digestibility of the silage (644 g DOM/kg DM) was on medium level and the preservation quality as indicated by pH value and contents of ammonia-N and fatty acids was good.

The mean initial LW of the bulls was 185 kg and the mean final LW 602 kg (Table III). The initial LW of the UB and PAD bulls was 8–9% higher than that of the IB bulls ($P<0.05$). This was partly due to the two animals lost during the experiment, because the lost IB bull was the heaviest one in the IB group and the lost PAD bull was the smallest one in the PAD group. There were no differences in final LW between the groups. The mean carcass weight of the bulls was 308 kg, being very close to the preplanned carcass weight. There were no effects of housing environment on the carcass weight or dressing proportion. The carcass fat score of both UB and PAD bulls was lower ($P<0.05$) than that of the IB bulls. The carcass conformation score of the UB bulls was higher ($P<0.05$) than the corresponding value of the IB bulls but there were no significant differences in the carcass conformation score between the IB and PAD bulls.

There were no significant differences in the LWG between the IB and UB bulls during the entire experiment or any sub-experimental periods. In contrast, during the winter periods the LWG of the PAD bulls was lower than that of the IB bulls ($P<0.05$). In addition, the LWG of the PAD bulls tended to be lower than that of the IB bulls ($P<0.1$) during the entire experiment. During the summer period there were no differences in LWG between the groups. DM (g/kg $W^{0.75}$) and energy intakes (MJ/kg $W^{0.75}$) of the IB bulls were

Table II. Chemical composition and feeding values of barley, grass silage and total mixed ration (mean ± SD[a]).

	Barley	Grass silage	Total mixed ration
Dry matter (DM), g/kg feed	913 ± 13.2	316 ± 27.3	428 ± 38.6
Organic matter, g/kg DM	976 ± 16.6	918 ± 52.8	948 ± 23.2
Crude protein, g/kg DM	110 ± 4.2	139 ± 12.1	127 ± 6.8
Neutral detergent fibre, g/kg DM	198 ± 5.9	616 ± 25.2	448 ± 14.4
Digestible organic matter in DM, g/kg DM	–	644 ± 22.6	
Metabolizable energy, MJ/kg DM	13.5 ± 0.1	10.3 ± 0.3	11.6 ± 0.2
AAT[b], g/kg DM	102 ± 1.1	78 ± 2.1	88 ± 1.6
Fermentation quality of silage			
pH		4.31 ± 0.2	
Volatile fatty acids, g/kg DM		14.6 ± 9.2	
Lactic and formic acid, g/kg DM		35 ± 15.9	
Water soluble carbohydrates, g/kg DM		33 ± 7.9	
In total N, g/kg N			
NH_4N		66 ± 21.7	
Soluble N		469 ± 51.9	

[a]Standard deviation.
[b]Amino acids absorbed from small intestine (MTT, 2006).

Table III. Body weights, daily gains, carcass characteristics, feed intake and feed conversion of bulls housed in insulated barn (IB), uninsulated barn (UB) and forest paddocks (PAD).

	IB	UB	PAD	SEM[b]	Significance[a] C1$_1$	C2$_1$
Initial live weight, kg	175	189	191	2.7	*	*
Final live weight, kg	616	608	583	13.2		
Carcass weight, kg	308	313	302	9.2		
Live-weight gain, g/d						
First winter (1 November 2000 to 18 April 2001)	1009	963	932	15.9		*
Summer (19 April 2001 to 3 October 2001)	1176	1093	1086	46.2		
Second winter (4 October 2001 to 9 December 2001)	1077	1079	788	55.5		*
Start to slaughter	1090	1037	972	29.4		****
Dressing proportion, g/kg[c]	500	515	516	6.5		
EUROP conformation[d]	4.4	5.0	4.6	0.13	*	
EUROP fat classification[e]	2.9	2.2	2.2	0.13	*	*
Dry matter intake, g/kg $W^{0.75}$						
First winter (1 November 2000 to 18 April 2001)	82.8	90.9	91.9	1.52	*	*
Summer (19 April 2001 to 3 October 2001)	93.2	105.6	105.4	0.79	**	**
Second winter (4 October 2001 to 9 December 2001)	83.3	93.8	93.0	1.37	*	*
Start to slaughter	86.1	96.4	97.7	0.85	**	**
Energy intake, MJ ME/kg $W^{0.75}$						
First winter (1 November 2000 to 18 April 2001)	0.96	1.05	1.07	0.018	*	*
Summer (19 April 2001 to 3 October 2001)	1.08	1.23	1.22	0.009	**	**
Second winter (4 October 2001 to 9 December 2001)	0.97	1.09	1.08	0.016	*	*
Start to slaughter	1.00	1.12	1.13	0.010	**	**
Feed conversion, kg DM/kg LWG						
First winter (1 November 2000 to 18 April 2001)	5.36	6.32	6.57	0.135	*	**
Summer (19 April 2001 to 3 October 2001)	7.69	9.40	9.37	0.266	*	*
Second winter (4 October 2001 to 9 December 2001)	9.43	10.23	13.90	0.351		**
Start to slaughter	7.03	8.33	8.80	0.159	*	**

[a]Differences between housing environments were compared using the *a priori* test (Dunnett's test) so that IB was used as a control. C1: IB vs. UB; C2: IB vs. PAD.
[b]Standard error of mean.
[c]Ratio of cold carcass weight to final live weight.
[d]EUROP conformation: (1 = poorest, 15 = excellent).
[e]EUROP fat cover: (1 = leanest, 5 = fattest).
Statistical significance: *$P<0.05$; **$P<0.01$; ***$P<0.001$; ****$P<0.10$.

significantly lower than those of the UB and PAD bulls during the entire experiment and also during all sub-experimental periods. In addition, the feed conversion rate (kg DM/kg LWG) of the IB bulls was better than that of the UB and PAD bulls during the entire experiment and during sub-experimental periods.

Behaviour

There were no differences in the total lying time between the UB and PAD bulls in winter or in summer (Table IV). The total lying time of the PAD bulls was significantly longer in winter than in summer ($P<0.001$). The total lying time of the UB bulls tended to be longer in winter than in summer ($P<0.1$). There were no differences in the time spent on lying on the bedded lying area between the UB and PAD bulls in winter or in summer. The UB bulls were observed to lie exclusively on the bedded lying area. The PAD bulls were not observed to lie outside the bedded lying area in winter at all, and even in summer lying on the forest area was very rarely observed. In summer, the PAD bulls spent totally more time on forest area than in winter ($P<0.05$). There were no differences in eating TMR, ruminating, self-grooming, social behaviour or other behaviours between the UB and PAD bulls in winter or in summer. Walking was observed more often in the PAD bulls than in the UB bulls in both seasons ($P<0.01$). Self-grooming ($P<0.01$) and social behaviour ($P<0.001$) were observed more often in summer than in winter in both groups. Ruminating was observed more often in winter than in summer in both groups ($P<0.05$). Other behaviours was observed more often in winter than in summer in the PAD bulls ($P<0.05$) and in the UB bulls there was a similar tendency ($P<0.1$). The PAD bulls were observed to graze and browse in summer. Shivering was not found in either housing environment.

Table IV. Percentage of observations (mean ± SD[a]) spent on different behavioural patterns in winter and summer between 00:00 and 24:00 hours in bulls housed in uninsulated barn (UB) and paddocks (PAD).

		UB	PAD	P1
Lying totally	Winter	61.6 ± 4.6	66.4 ± 8.4	NS
	Summer	55.0 ± 5.2	50.3 ± 5.5	NS
	P2	****	***	P3****
Lying on bedded lying area	Winter	61.6 ± 4.6	66.4 ± 8.4	NS
	Summer	55.0 ± 5.2	50.0 ± 5.2	NS
	P2	*	***	P3*
Lying on concrete floored feeding area	Winter	0.0	0.0	–
	Summer	0.0	0.0	–
	P2	–	–	P3–
Lying on forest area	Winter	–	0.0	–
	Summer	–	0.3 ± 0.5	–
	P2	–	–	P3–
Totally on forest area	Winter	–	12.6 ± 6.3	–
	Summer	–	22.8 ± 3.4	–
	P2	–	*	P3–
Eating TMR	Winter	15.4 ± 2.9	16.3 ± 2.0	NS
	Summer	15.4 ± 3.6	16.7 ± 4.8	NS
	P2	NS	NS	P3 NS
Grazing and browsing	Winter	–	0.0	–
	Summer	–	2.1 ± 1.3	–
	P2	–	–	P3–
Ruminating	Winter	40.3 ± 3.7	38.7 ± 4.1	NS
	Summer	35.8 ± 3.9	34.9 ± 4.7	NS
	P2	**	*	P3 NS
Self-grooming	Winter	0.5 ± 0.4	0.5 ± 0.4	NS
	Summer	3.6 ± 1.5	2.5 ± 1.5	NS
	P2	***	**	P3 NS
Social behaviour	Winter	4.3 ± 3.3	2.2 ± 2.1	NS
	Summer	11.3 ± 3.4	8.4 ± 3.3	NS
	P2	***	***	P3 NS
Walking[b]	Winter	0.4 ± 0.3	1.8 ± 1.2	**
	Summer	0.1 ± 0.2	1.2 ± 0.7	***
	P2	****	NS	P3 NS
Other behaviours	Winter	39.5 ± 6.1	40.6 ± 4.6	NS
	Summer	34.1 ± 5.3	34.3 ± 7.7	NS
	P2	****	*	P3 NS
Shivering	Winter	0.0	0.0	–
	Summer	0.0	0.0	–
	P2	–	–	P3–

[a]Standard deviation. P1: significance between housing environments, P2: significance within housing environments between seasons, P3: significance of interaction between housing environment and season.
[b]P-values are based on comparisons of estimated marginal means of ln $(x+1)$ transformed variable.
Statistical significance: *$P<0.05$, **$P<0.01$, ***$P<0.001$, ****$P<0.10$, NS $P>0.10$.

The diurnal rhythms of the UB and PAD bulls were more similar between the housing environments than between the seasons as can easily be perceived in Figures 3 and 4. In both seasons, eating activity was most evident after feeding in the morning, noon and evening. In winter, an additional eating period was observed around midnight in the UB, but not in the PADs. In winter, other behaviours occurred mostly during daytime. In summer, the bulls were observed to perform other behaviours later, even until 01:00 hours, than in winter. On the other hand, the bulls lay longer period from evening to morning in winter than in summer. Eating and other behaviours were at minimum in the early morning when the bulls were lying.

Immune status

In winter, there was a tendency for serum IgG level to be highest in the IB bulls and lowest in the PAD bulls (Table V) ($P<0.1$). Immune status was higher in all groups in summer than in winter ($P<0.01$). Furthermore, in summer, serum IgG was higher in the IB bulls than in the UB or PAD bulls ($P<0.01$).

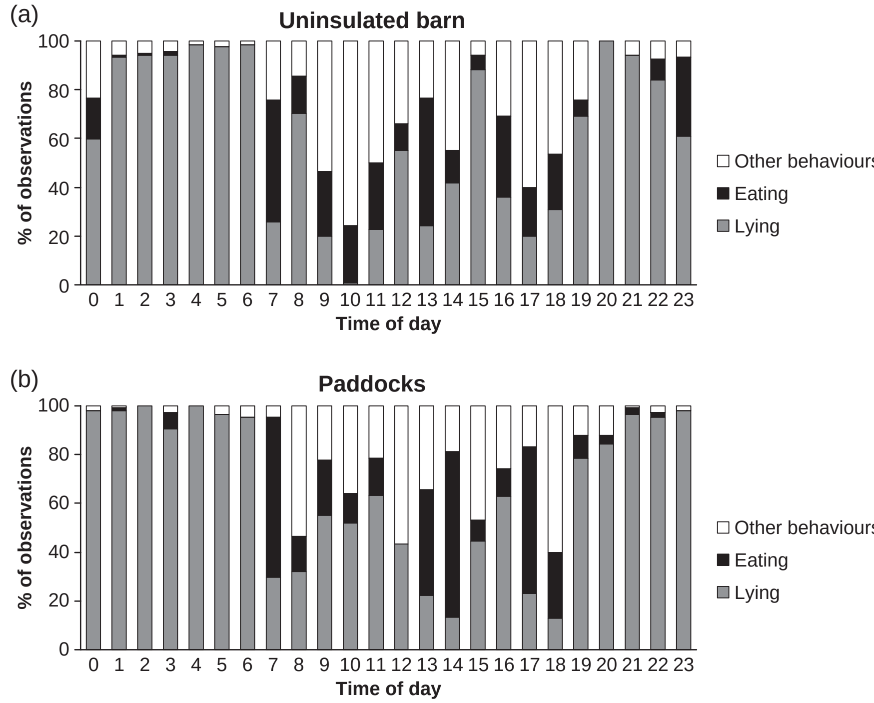

Figure 3. The proportion of other behaviours, eating and lying activities in February in different hours of the day in bulls housed in uninsulated barn (a) and paddocks (b). The time of sunrise was approximately 08:40 and sunset 16:25 during the observations.

Discussion

In the present experiment we compared performance and immune status of growing dairy bulls housed in an UB, in forest PADs and in tie-stalls. In addition, the behaviour of the bulls housed in the UB and in forest PADs was investigated during winter and summer. The behaviour of the bulls housed in the IB was not observed, because the direct observation

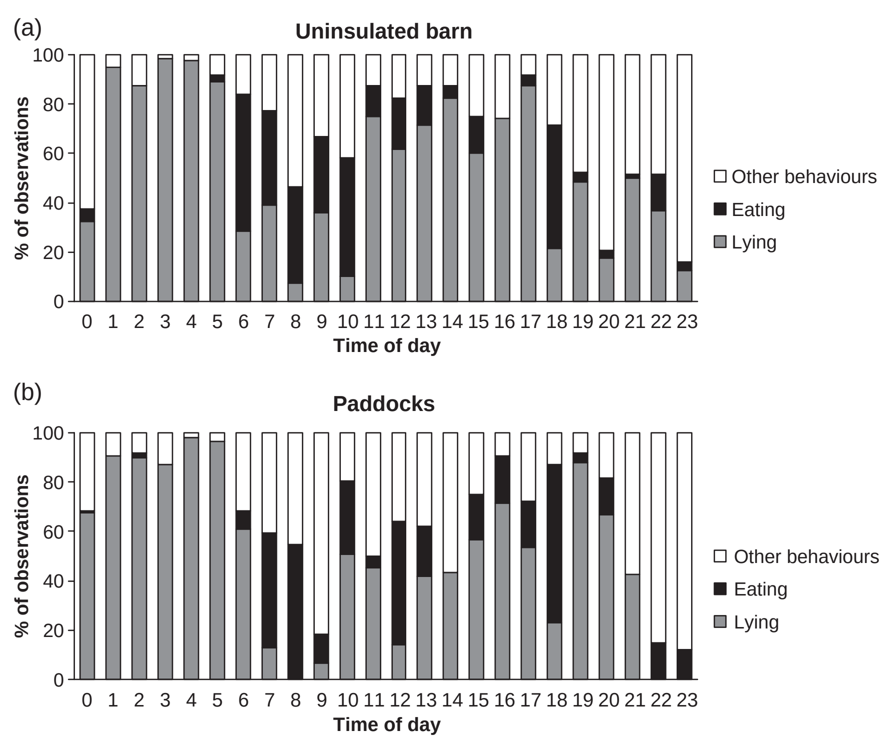

Figure 4. The proportion of other behaviours, eating and lying activities in July in different hours of the day in the bulls housed in uninsulated barn (a) and paddocks (b). The time of sunrise was approximately 03:15 and sunset 23:30 during the observations.

Table V. Total IgG concentration (mean ± SD[a]) of serum of bulls housed in insulated barn (IB), uninsulated barn (UB) and paddocks (PAD) in winter and summer.

		IB	UB	PAD	P1
IgG, mg/ml[c]	Winter	5.8 ± 1.8	4.3 ± 1.1	3.5 ± 0.7	****
	Summer	15.0 ± 6.9[a]	6.5 ± 1.6[b]	5.5 ± 1.3[b]	**
	P2	***	**	**	P3**

[a]Standard deviation.
[a,b]Figures without a common letter within the category are statistically different ($P < 0.05$) within the season.
[c]*P*-values are based on comparisons of estimated marginal means of ln $(x+1)$ transformed variable.
P1: significance between housing environments, P2: significance within housing environments between seasons, P3: significance of interaction between housing environment and season.
Statistical significance: *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.10$.

method used in this study was not suitable for a tie-stall environment. In the tie-stall environment, the observer would have had to walk by the side of the animals in order to see them properly and this movement would have disturbed the animals to some extent. In the uninsulated environments the observer was still, thus disturbing the bulls less.

Feed intake and feed conversion

In the present study, DM and energy intakes of the UB and PAD bulls were higher and the feed conversion rate was worse than that of the IB bulls during the entire experiment. One possible explanation for these differences between the groups during winter could be that the outdoor bulls had higher energy requirements for maintenance in cold. For example, it has been found that calves housed at −4°C required 32% more energy for maintenance than calves housed at +10°C (Scibilia et al., 1987). However, in the present study the differences in DM and energy intake as well as feed conversion between the IB bulls and the bulls in uninsulated environments were similar or even more obvious during the summer period than during the winter periods. Similarly, in our earlier experiment with Hereford bulls the treatment differences in the DM and energy intakes between insulated and uninsulated environments were equal or even higher during the summer than during the winter periods (Huuskonen et al., 2009). This indicates that thermal conditions may not have been a major reason for increasing intakes in uninsulated housing environments compared to insulated tie-stalls. Rather, the energy expenditure of walking and other exercise had a more important effect on the intake and feed conversion. Although we did not have a possibility to measure distances which the bulls travelled daily, it is obvious that energy expenditure for moving in the uninsulated environments was clearly higher than that in the tie-stalls. The energy cost of walking and working in cattle has been extensively researched (e.g. Lawrence & Stibbards, 1990; Dijkman & Lawrence, 1997). According to Dijkman & Lawrence, (1997), the energy cost of moving 1 kg body weight 1 m forward was 1.47 J/m/kg for the *Bos indicus* cattle on smooth ground. Lawrence and Stibbards (1990) reported an average energy expenditure of 2.09 J/m/kg for *Bos indicus* and *Bos taurus* cattle on treadmills. Supposing that the energy expenditure for walking would be 2.0 J/m/kg, a 500 kg bull travelling 2 km in the course of 24 hour would thus expend 2.0 MJ ($500 \times 2000 \times 2.0$ J).

Our results indicate that Finnish environmental conditions do not necessarily increase feed or energy intakes of growing dairy bulls, but the energy expenditure of walking and other exercise increases clearly with outdoor housing compared to housing in tie-stalls. In addition, it is possible that a small part of feed given to the UB and PAD bulls in the present experiment was wasted and not consumed since the feeding trough used outdoors was not optimal and it was more difficult to recover and weigh residues outdoors than in the IB.

Growth and slaughter parameters

In the present study the LWG during the entire experiment tended to be higher in the IB bulls than in the PAD bulls. However, there were no differences in the LWG between the IB and UB bulls. In earlier studies in Scandinavia, Mossberg et al. (1992, 1993) reported no difference in LWG between dairy bulls housed in insulated and uninsulated buildings at latitude 58°N. Redbo et al. (1996) found no difference in LWG during the winter period between dairy steers housed on slatted floors and outdoors in field at latitude 60°N which corresponds to the latitude of Southern Finland. In a study of Manninen et al. (2007) in Tohmajärvi at latitude 62°N, beef heifers housed in an uninsulated housing environment grew as well as or even better than heifers housed in an insulated building. In our earlier experiment with Hereford bulls, the average LWG of the bulls was higher in the uninsulated environment than in the insulated tie-stall (Huuskonen et al., 2009). In the present study, the LWG of the PAD bulls was lower than that of the IB bulls during the winter periods, but the explanation for this effect is not clear.

In the IB the bulls were tied and, therefore, the IB bulls did not have a possibility to exercise. This difference in exercise between the outdoor housing environments and the IB might explain why the carcass conformation score of UB bulls tended to be higher and the carcass fat score of the UB and PAD bulls was lower than the corresponding values of the IB bulls. The idea that increased exercise can explain the differences in leanness is supported by Levy et al. (1970) and Mossberg et al. (1992). Mossberg et al. (1992) reported that bulls housed in an uninsulated building had less fat in their carcasses than bulls housed in an insulated building. The authors concluded that the animals in the uninsulated building had a higher energy requirement for maintenance and activity than the animals housed inside on slatted floors.

Behaviour

The UB bulls were observed to lie exclusively on the bedded lying area as has previously been found in similar housing systems (Lidfors, 1992; Tuomisto et al., 2008). The PAD bulls were not observed to lie outside the shelter in the winter at all, and even in summer lying on forest area was very rarely observed. On the contrary, Redbo et al. (1996) reported that steers housed in field equipped with shelter used to lie down in the snow during daytime. In the present study, the bulls showed strong preference for lying on bedded lying area which indicates that provision of bedded lying area and shelter is likely to have positive effect on the welfare of outdoor housed bulls (see e.g. Broom & Johnson, 1993). This statement is supported by studies reporting that providing animals bedded lying area (Birkelo & Lounsbery, 1992) or shelter to protect animals against wind and rain (Hoffman & Self, 1970; Kubisch et al., 1991) improves weight gain in cattle.

In the present study, neither housing environment nor season had any effect on the time spent on eating TMR. Eating activity was most evident after addition of feed as was found also by Cozzi and Gottardo (2005). Gonyou and Stricklin (1984) reported a significant period of eating occurring near midnight during the longer winter night, but with increasing day length the duration and intensity of the eating period decreased. In the present study, eating near midnight occurred only in the UB bulls in winter. Grazing and browsing observed in the PAD bulls in summer had only a minimal effect on their nutrient supply, because they were able to ingest only some bushes, leaves and twigs. According to Young (1983), increased rumination activity, together with some other digestive changes, is a result of exposure to cold. In the present study, however, it is not clear whether the higher ruminating time in winter when compared to summer was caused by low winter temperatures or whether it reflected ontogenetic changes in the bulls' physiology with increasing age.

In both housing environments the bulls were observed to perform self-grooming more in summer than in winter. This may have been associated with increased activity of the bulls in summer and presence of insects. In addition, the PAD bulls spent more time in forest area in summer than in winter. In forest there was a lot of suitable objects (e.g. trees and big rocks), for scratching which may have contributed self-grooming activity in summer.

There were no significant differences between the UB and PAD bulls in time spent performing social behaviours, i.e. social licking, butting and other social behaviours, including sexual behaviour. This is in agreement with findings of Tuomisto et al. (2008) with Hereford bulls in similar housing environments. Furthermore, the bulls performed social behaviour more in summer than in winter which may to some extent reflect ontogenetic changes in the bulls' behaviour with increasing age. It should also be noted that due to the relatively high space allowance in the UB the UB bulls may have encountered agonistic behaviour less than could have been observed in more crowded conditions. The higher proportion of walking in the PAD bulls compared with the UB bulls was probably a natural consequence of the larger living area in the forest PADs. Walking during grazing and browsing was not taken into account in our study, and therefore the PAD bulls were in summer actually moving even more than the current results indicate.

The diurnal rhythms of the UB and PAD bulls were more similar between the housing environments than between the seasons, and it seems that day length had a strong effect on the distribution of lying and other behaviours (behaviours performed in standing position excluding eating TMR) over the day. In winter, other behaviours occurred mostly during daytime. In summer, on the other hand, the bulls were observed to lay more in the afternoon and perform other behaviours later, even after midnight, than in winter. In both seasons, in accordance with observations of Gonyou and Stricklin (1984), there was a period of minimal eating and performance of other behaviours in the early morning when the bulls were lying.

Shivering was not found during the observations, however, Blaxter and Wainman (1964) stated that the muscle movements of shivering can be so minute that casual observation fails to detect them, especially if cattle have full coats. Gonyou et al. (1979) states that the ability to withstand increasingly colder temperatures without shivering as the winter progresses indicates that shivering is affected by acclimatization. In the present study the bulls were gradually acclimatised to cold, because they were kept outside since the previous summer, resulting in no shivering in February when the observations took place, even in the lowest temperature of $-25°C$.

Immune status

In farm animal production it is widely believed that the negative economic impact of disease is potentiated in stressed animals. The assumption that stress influences host immunity arises from observations of increased disease occurrence in animals exposed to extreme, stressful environments (Blecha, 2000). In the present study, immune (IgG) status was lower in winter than in summer in all groups. In addition, in the IB bulls this change in immune level was more intense than in the UB or PAD bulls. The higher immune status of all groups in summer than in winter may indicate an overall increase in antigens in the immediate surrounding of bulls as the temperature rose. In the IB the hygiene of the animals' immediate surrounding in summer was likely worse than in the outdoor environments.

Conclusion

Our study indicates that finishing dairy bulls can be overwintered outdoors with reasonable LWGs in Northern Finland without warm housing facilities. This conclusion requires that the facilities provided for the bulls are at least equal to those of the present experiment. Compared with the tie-stall system, the energy expenditure of walking and other exercise increases in outdoor housing systems, which means also increased energy intake and reduced feed conversion rates. Behavioural study showed that the time budgets and diurnal rhythms of the bulls housed in an UB and in the forest PADs were quite similar. It seemed that season and/or age of the bulls had a greater impact on the bulls' behaviour than the housing environment itself. The bulls showed strong preference for lying on bedded lying area which indicates that provision of bedded lying area and shelter is likely to have positive effect on the welfare of outdoor housed bulls. The measures of immune (IgG) level indicate that the hygiene of the bulls' surroundings decreased in summer, especially in the IB.

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