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Does rubber flooring improve welfare and production in growing bulls in fully slatted floor pens?

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Abstract

This study compared the effects of concrete slats (CS), synthetic rubber slats on aluminium profiles (RS) and slotted rubber mats on concrete slats (RM) in fully slatted floor pens on behaviour, claw and leg disorders, claw horn growth, cleanliness and production parameters of growing dairy bulls from 225 to 650 kg average liveweight. Each pen housed five bulls up to 400 kg average liveweight and four bulls thereafter. On CS, lying bouts were less frequent and longer than on RM and RS at 250 kg. Lying down phase 1 was longest on CS and shortest on RM. Interrupted attempts at lying down occurred twice as often on CS as on the rubber floors. Severity scores for white line haemorrhage and sole haemorrhage were higher in bulls on CS than on RM. Swelling on legs had highest scores on CS, whereas the severity score for heel horn erosion was lowest on CS. Floor type had no effect on dermatitis, leg hairlessness and skin damage. Both claw horn growth and wear were greater on CS than on RS and RM. Bulls on RS and CS were cleanest. Slaughter age tended to be higher and carcase conformation score tended to be lower on CS than on rubber, whereas feed intake, feed efficiency and other carcase traits were unaffected. The results indicate that rubber flooring improves animal welfare compared with concrete.

Keywords: *animal welfare, behaviour, cattle, claw health, cleanliness, performance*

Introduction

Housing growing animals in fully slatted floor pens is a common system in many European countries. The animals are traditionally kept on concrete slats or, in some cases, wooden slats with the gaps between the bars serving as drainage of waste material. The advantages of the system are low labour and space demands and efficient manure management without litter, in combination with reportedly clean animals (Scott & Kelly 1989; Lenehan & Fallon 2002).

However, concrete is reported to cause more interrupted lying down movements and fewer lying bouts, to be more slippery and to be a less preferred lying area for growing cattle compared with softer materials, such as rubber mats and deep straw bedding (Ruis-Heutinck *et al* 2000; Gygax *et al* 2007a; Platz *et al* 2007; Zerbe *et al* 2008). Hard surfaces cause compression lesions and leg diseases, such as carpal bursitis and periarthritis (inflammation of the tissue around the joint) in growing cattle and overwork carpal joints during lying down and standing up (Metzner 1978; Stanek 1997; Schulze Westerath *et al* 2007). In a study on dairy cows, laminitis and claw injuries caused by trauma decreased when concrete alleyways were covered with rubber (Benz & Wandel 2004). Hygiene-related diseases, such as interdigital dermatitis and heel horn erosion, are reported to decrease on drained floors, irrespective of whether they are made of concrete or covered with rubber (Thysen 1987; Hultgren & Bergsten 2001). Floor abrasiveness affects claw horn growth and wear and claw conformation, which affects susceptibility to claw lesions (Telezhenko *et al* 2008).

Cleanliness is important for both animal welfare and food safety. A dirty coat causes discomfort and wounds in the skin, and increases the risk of meat contamination at slaughter (Bosilevac *et al* 2005). Having a higher proportion of drainage area influences cleanliness positively, which can be a disadvantage with rubber mats, which have less drainage area than slatted concrete floors (Lowe *et al* 2001; Fallon & Lenehan 2002). The cleanliness of the animals is also influenced by manure consistency, which is influenced by feed and diet (Davies *et al* 2000; Fallon & Lenehan 2002).

Hypothetically, improving animal welfare can result in higher production. However, Lowe *et al* (2001) did not find any effect of floor type on weight gain or carcase composition in growing cattle.

The aim of this experiment was to investigate the influence of a slatted concrete floor and two types of rubber flooring on behaviour, claw and leg disorders, claw horn growth, cleanliness and production in growing cattle. Unlike most other studies, we took a more comprehensive approach by studying multiple welfare parameters on the same animals.

Materials and methods

Housing and animals

This study was conducted at Götala Research Station, Swedish University of Agricultural Sciences, Skara, southwest Sweden, from November 2007 to December 2008. Eighty newly weaned bull calves of Swedish Holstein breed with a mean liveweight of 100 kg (SD 18) were bought from commercial herds. During the pre-experimental period of 14 weeks, the calves were kept in a non-insulated barn with deep straw bedding until 225 kg (SD 33) liveweight. The insulated barn used for the experiment had 16 fully slatted floor pens, each measuring 365 × 294 cm (length × breadth) and distributed in two rows. Underneath the slatted flooring, waste material was scraped, once daily, and removed to a slurry pit outside the barn.

Diets and feeding

A total mixed ration was provided *ad libitum* in one feed trough per pen once a day at around 0700h. The diet was composed of 40% grass-clover silage and 60% rolled barley on a dry matter (DM) basis. Vitaminised mineral supplements were fed in adequate amounts. Leftovers were weighed and disposed of three times a week and net average daily feed intake per animal was calculated. Before mixing, silage samples were taken daily and pooled to one sample per week for DM analysis and to one sample per month for analysis of the chemical composition. Samples of barley were collected weekly and pooled to one sample every other month for analysis of the chemical composition.

Average DM concentration determined at 60ºC for 24 h was 341 g kg^{-1} for silage and 855 g kg^{-1} for barley, while crude protein concentration was 164 g kg^{-1} DM for silage and 111 g kg^{-1} DM for barley (Tecator Kjeltec Auto sample system 1035 Analyzer, Tecator Inc, Sweden). The average concentration of neutral detergent fibre was 523 g kg^{-1} DM for silage (Goering & Van Soest 1970) and 162 g kg^{-1} DM for barley (Van Soest *et al* 1991). In barley, the average concentration of starch was 631 g kg^{-1} DM and the average concentration of crude fat was 31 g kg^{-1} DM (Åman & Hesselman 1984; Commission of the European Communities 1998). The metabolisable energy concentration (ME) of silage was 10.8 MJ kg^{-1} DM, calculated from *in vitro* organic matter digestibility (Lindgren 1979), while the ME of barley was 13.3 MJ kg^{-1} DM, calculated according to Axelsson (1941).

Experimental outline

Two weeks prior to the start of the experiment, all calves' coats were cut in order to standardise cleanliness and they were randomly allocated to groups of five, controlled for similar mean liveweight and variation. These groups were then randomly allocated to one of 16 pens in the insulated cattle barn. The following three flooring types were used in the experiment:

• Concrete slats (CS), 30 years old, single slats of 125-mm width with 38-mm slots, drainage area 21% (six pens);

• Rubber slats (RS), profiled aluminium bars covered with 15-mm thick synthetic ethylene propylene diene monomer rubber with slightly convex-formed smooth surface, 125-mm slat width with 35-mm slots, drainage area 20%, hardness shore 70A (Rubber-Slat®, Fritz Foderstyrning AB, Sweden) (five pens); and

• Slotted rubber mats (RM), 20-mm thick rubber mats with tailor-made 38-mm wide slots to fit the concrete slats underneath, manufactured with a patterned surface, drainage area 14%, hardness shore 60A (softest floor in this study) (LOSPA, Gummiwerk Kraiburg Elastik GmbH, Germany) (five pens).

The different floor types were evenly distributed on both sides of the feeding alley so that each floor type appeared at least once at the end of a row of pens and was adjacent to each of the other floor types. The floors were maintained for function but not manually cleaned.

For all bulls, behaviour, claw and leg disorders, claw horn growth and wear, cleanliness and production parameters were recorded. The test occasions for behaviour, claw and leg disorders and claw horn growth and wear were defined as 'weight classes' (250, 450, 650 kg) and data from all animals kept during the respective test occasions were included in the analyses of these parameters. Data on weight gain and carcase measurements only included animals kept in the experiment until slaughter.

At a mean liveweight of 400 kg, the lightest bull in each pen was removed and excluded from the experiment and the remaining animals were kept in groups of four until slaughter. The bulls were slaughtered in a commercial abattoir when they had reached 650 kg liveweight on an individual level. No cutting, grooming or washing of the coat was carried out prior to slaughter.

In total, five animals were replaced: one bull due to pneumonia (on concrete slats), three bulls because of severe lameness (two bulls on concrete slats and one bull on rubber mats) and one bull because of a fractured leg (on rubber slats). The replacement bulls were taken out at 400 kg and excluded from analyses. A second bull (on rubber slats) fractured a leg one week prior to the last measurements and was therefore not replaced.

The Ethical Committee on Animal Experiments in Gothenburg, Sweden approved the protocol and execution of this study.

Behaviour

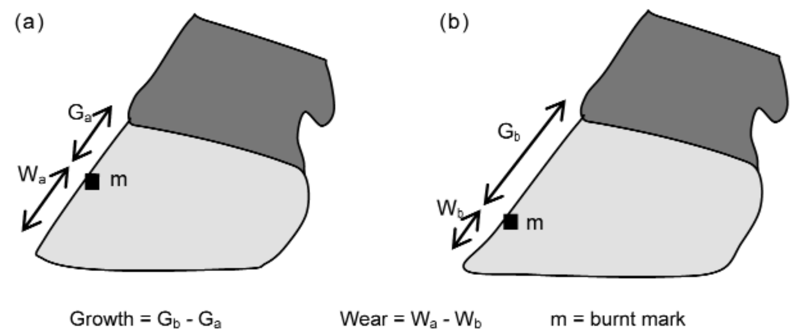
At the three weight classes, 250 kg (one week after housing in the insulated barn), 450 kg (four months later), and 650 kg (another five months later), all pens were filmed with a MSH-Video Client 4.5.11.123 (M Shafro & Co, Latvia) 0000–2400 h. The cameras, recording one image per second, were attached to the ceiling of the main aisle (height 2.4 m). From the films, the behaviour was recorded only during the light period (0600–1800h). The same observer recorded duration and frequency of different behaviours, including lying down phase 1 and 2, using continuous focal animal sampling (Table 1). The individuals were identified by the different patterns on their coat.

Table 1 Definition of the recorded behaviours of growing bulls on the three floor types and indication of whether the behaviour was recorded as duration (D) or frequency (F).

Behaviour	Data	Definition
Lying	D + F	Body touches floor, no weight on legs
Lying down phase 1	D	Sniffing floor for at least 3 s, ends before the first carpal joint reaches the floor
Lying down phase 2	D	Starts with the first carpal joint reaching the floor, hind quarters are lowered, stops when bull is lying
Interrupted attempt at lying down	F	Either lying down phase 1 or 2 is interrupted by stopping sniffing or standing up during phase 2 without continuing the lying down movement
Mounting	F	One bull has or tries to get his forelegs around the abdomen of another and is standing/walking solely on its hind legs
Lying down abnormally	F	Lying down via dog-sitting or lowering forepart or hindquarters equally, not using carpal joints to carry bodyweight
Standing up abnormally	F	Standing up horse-like by taking a dog-sitting position and swinging the weight forward with straight forelegs, not using the carpal joints
Outer tongue rolling	D	Sticking out tongue and rolling it in mid-air, often with a rather straight head-neck line
Nose pressing	D + F	Excessively pressing the nose against hard objects

Figure 1

Growth and wear of the claw horn assessed by measuring the displacement of a burn mark on the dorsal wall from (a) the first examination at 450 kg to (b) the second examination at 650 kg. G: distance coronary band; mark W: distance mark–toe tip.



Claw and leg disorders

Claw and leg disorders of bulls were examined at weight classes 450 and 650 kg by a well-trained researcher in blind tests no longer than a few days after the behavioural observations. At the first claw examination at 450 kg, only a thin layer of claw horn was pared off with a hoof knife to make claw lesions visible, whereas at the second examination at 650 kg the claws were fully trimmed. All claw lesions were recorded separately on all eight claws, except for dermatitis, which, along with leg lesions, was recorded separately on all four feet/legs. The claw lesions were recorded even if they disappeared during trimming. Heel horn erosion, dermatitis, sole haemorrhage (including sole ulcer) and white line haemorrhage were scored according to the Swedish national claw recording scheme (www.slu.se) with a 3-graded ordinal scale: 1) no lesion; 2) slight lesion; and 3) severe lesion. Leg lesions of carpal and tarsal joints were described as hairlessness, skin damage and swelling. Lesions on each leg were recorded on a 3-graded ordinal scale for each parameter as follows: hairlessness; 1) no hairlessness; 2) hairless part at most 10 cm^2; and 3) hairless part larger than 10 cm^2; skin damage; 1) no skin damage; 2) slight skin damage (≤ 2 cm^2), no sign of inflammation; 3) severe skin damage (> 2 cm^2) or inflamed wound regardless of size; swelling; 1) no swelling; 2) light swelling, hardly visible but diagnosed by palpation; and 3) severe swelling, clearly visible.

Claw horn growth and wear rate

Growth and wear of the left outer hind claw were recorded by measuring the displacement of a distinct reference mark burnt into the horn wall with a soldering gun. At the first examination at 450 kg and the second examination at 650 kg, the displacement was examined by the same person in blind tests using a Vernier calliper. The difference in the distance between mark and coronary band between measurements was defined as the absolute growth (Growth; Figure 1) and the difference in the distance between mark and toe tip between measurements was defined as the absolute wear (Wear; Figure 1). Net growth was calculated by subtracting the absolute wear from the absolute growth. The monthly growth, wear and net growth were then calculated and used in analyses.

Cleanliness

Cleanliness was assessed on each animal once a month by the same person in blind tests, with the first observation two weeks after the start of the experiment and the last observation two weeks before the occasion of the first slaughter. The body was divided into the following four parts: 'Back': head, neck and back, excluding rump; 'Front': dewlap and forelegs; 'Belly': lower part of abdomen between forelegs and hind legs; and 'Rear': rump, hind legs and tail. Each body part was rated separately on a 5-graded ordinal scale: 0) clean coat, no visible manure; 1) some manure visible, manure distributed over less than 20% of the surface; 2) sparsely distributed manure, manure distributed over less than 50% of the surface; 3) 50% or more of the surface dirty, no thick manure layer or sparsely distributed big spots of manure; and 4) whole or almost whole surface covered with manure, thick manure layer.

Production parameters

The liveweight of each bull was recorded once every second week and on two consecutive days at the start of the experiment and before slaughter. Average daily liveweight gain (ADG), feed efficiency and feed intake were calculated from the start of the experiment at 225 to 400 kg average liveweight; from 400 kg average liveweight to slaughter; and from the start of the experiment to slaughter.

After slaughter, cold carcase weight (0.98 × warm carcase weight) was recorded and dressing-out percentage defined as carcase weight:liveweight at slaughter. Conformation and fatness were graded according to the European Union Carcass Classification Scheme EUROP, modified to the Swedish system where 15 classes are used (SJVFS 1998; Commission of the European Communities 2005). The EUROP classes were transformed to numerical figures for conformation score (1 = poorest and 15 = best) and fatness (1 = leanest and 15 = fattest).

Statistical analysis

Behaviour

When viewing the data graphically prior to analysis, we saw that the effect of floor differed in the different weight classes and we assumed that the power in our test with so few degrees of freedom would not be enough to elucidate this difference. Therefore, normally distributed behaviour was analysed with a general linear model (the GLM procedure in SAS 9.1, SAS Institute Inc, USA), for each weight class (250, 450, 650 kg). The effect of floor type (CS, RS, RM) was tested. The data entering the analyses were mean values per pen (n = 16). The results are presented as least square means (LSM) with standard errors (SEM). Multiple comparisons of LSM were made with the $LSD_{0.05}$-test. Lying down phase 1 and mounting were not normally distributed and the effect of floor was therefore analysed with the Kruskal-Wallis test (Minitab 15.1.1.0, Minitab Inc, USA). Median time of lying down phase 1 and sum of mountings were calculated per pen and used in the analysis. One pen with RS was excluded from the behavioural analyses at 650 kg as it housed the group of the unreplaced bull.

Claw and leg disorders and claw measurements

To emphasise the clinical importance of more severe lesions the original scores of claw and leg lesions were converted in geometric series $2^{(\text{severity}-1)}$ as described in Leach *et al* (1998). These weighted scores of every claw or limb were then summarised for each animal.

The analyses of claw and leg health data were carried out on pen level, ie the mean values of the weighted score sums per pen were subjected for the analyses. The models were fitted with a mixed linear model (PROC MIXED procedure, SAS 9.1, SAS Institute Inc, USA). The models included the following sources of variation: the fixed effects of floor type (CS, RS, RM), weight class (450, 650 kg), their interaction and the pen as a random factor. For those lesions where residuals did not meet the assumptions of normality and homoscedasticity the log transformation was applied. To present results, the back-transformation for these outcomes was used. Multiple comparisons of the means were made with Tukey's adjustment. The analyses of claw horn growth and wear rate were also performed on pen level with a similar model as described above.

Cleanliness

Since the body part, 'Back' was always clean with some random exceptions, this was excluded from analysis. For the statistical analysis, the cleanliness score was summarised from the start of the experiment to 650 kg average liveweight for each body part of the individual bull. The summarised scores were normally distributed and analysed on pen level with a mixed linear model (PROC MIXED procedure, SAS 9.1, SAS Institute Inc, USA). In the model, the fixed factors were floor type (CS, RS, RM), body part (Belly, Front, Hind) and the interaction between floor type and body part. Pen was included as a random factor. Multiple comparisons of LSM were made with Tukey's adjustment.

Production parameters

Production parameters were investigated on pen level with a general linear model (PROC GLM procedure in SAS 9.1, SAS Institute Inc, USA). In the model, the fixed factor was floor type (CS, RS, RM) and pen was included as a random factor. The results are presented as LSM with SEM. Multiple comparisons of LSM were made with the $LSD_{0.05}$-test.

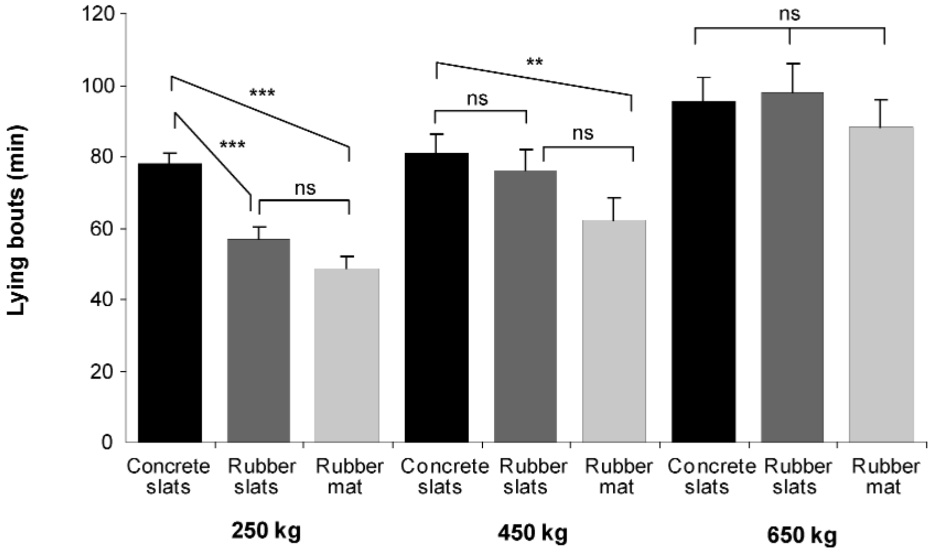
Results

Behaviour

The duration of lying bouts was significantly affected by floor type at weight class 250 kg (F = 25.24, df = 2, $P < 0.001$). Lying bouts were significantly longer on CS than on both rubber floors (Figure 2). Except for a tendency for longer lying bouts on CS compared to RM at 450 kg, no differences in the duration of lying bouts between the floor types were found at 450 and 650 kg (Figure 2).

Average total lying time per 12 h was 6 h, 16 min and did not differ between the floor types. With increasing weight class, the average total lying time per 12 h increased from 5 h 17 min at 250 kg, to 6 h 13 min at 450 kg and 7 h 40 min at 650 kg.

Figure 2



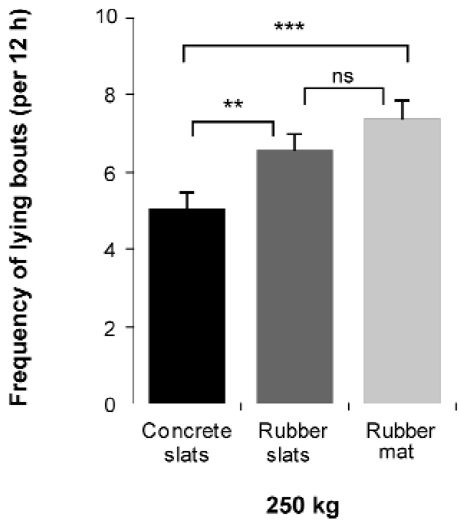
Least square means (± SEM) of lying bouts (min) on the three floor types for three weight classes. *** $P < 0.001$; ** $0.05 < P < 0.1$.

The frequency of lying bouts per 12 h differed significantly between the floor types at weight class 250 kg ($F = 8.5$, df = 2, $P < 0.05$). Bulls housed on CS lay down significantly less frequently than bulls on RM and they tended to lie down less frequently than bulls on RS (Figure 3). There was no significant difference in this behaviour at weight classes 450 and 650 kg. The frequency of interrupted attempts at lying down was significantly higher on CS than on either of the rubber floors at 450 kg and significantly higher on CS than on RM at 650 kg (Figure 4). At 250 kg, the bulls on CS tended to interrupt their attempts at lying down more often than bulls on either rubber floors (RS: $P = 0.063$, RM: $P = 0.061$). In total, the bulls on CS had 2.4 interrupted attempts at lying down per completed lying down movement, whereas they had 1.0 on RS and 0.7 on RM.

There were significant differences in the duration of lying down phase 1 between the floor types ($H = 7.87$, df = 2, $P < 0.05$; Figure 5) with the longest duration on CS and the shortest on RM.

We did not observe any differences in the duration of lying down phase 2 between floor types. The duration of lying down phase 2 increased from 4 s at 250 kg to 6 s at 650 kg. The number of mountings tended to differ between the floor types ($H = 5.24$, df = 2, $P = 0.073$; $CS_{med} = 8$, Q1 = 5, Q3 = 33; $RS_{med} = 21$, Q1 = 10, Q3 = 39; $RM_{med} = 51$, Q1 = 35, Q3 = 65). Abnormal lying down and standing up behaviour occurred in total on 29 occasions during observations, in 21 of which the bulls sat in dog-like positions during the movements, while in the remaining eight the bulls lowered their fore- and hind-quarters equally, not using their carpal joints as support during the lying down movement. All dog-sitting incidents except for one occurred on CS.

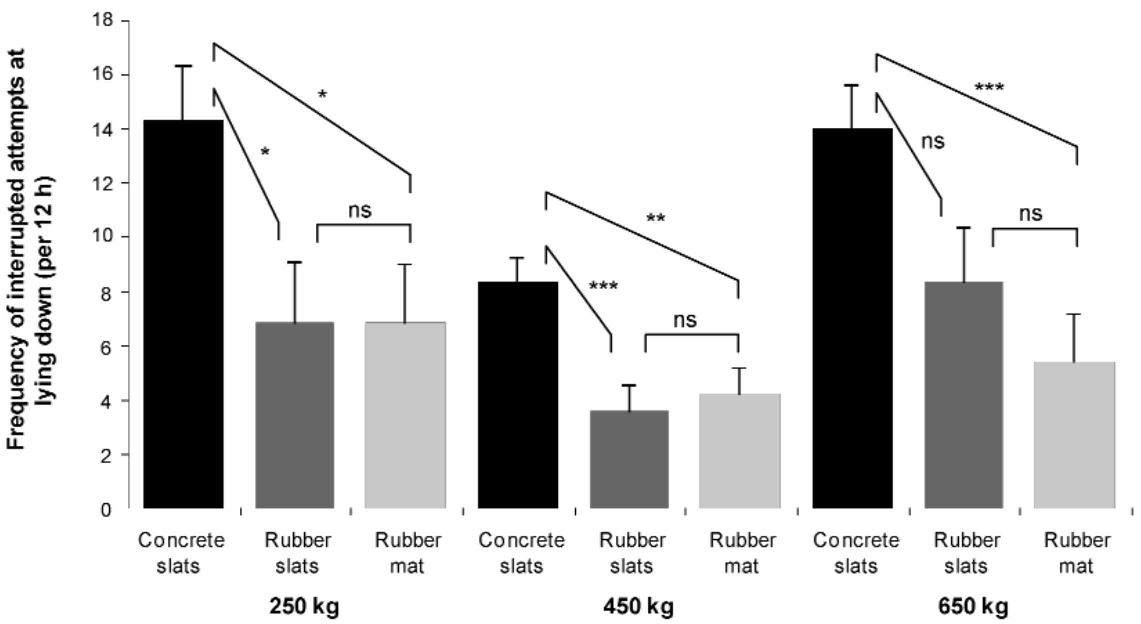
Figure 3



Mean (± SEM) number of lying bouts per 12 h on the three floor types for weight class 250 kg. *** $P < 0.001$; ** $0.05 < P < 0.1$.

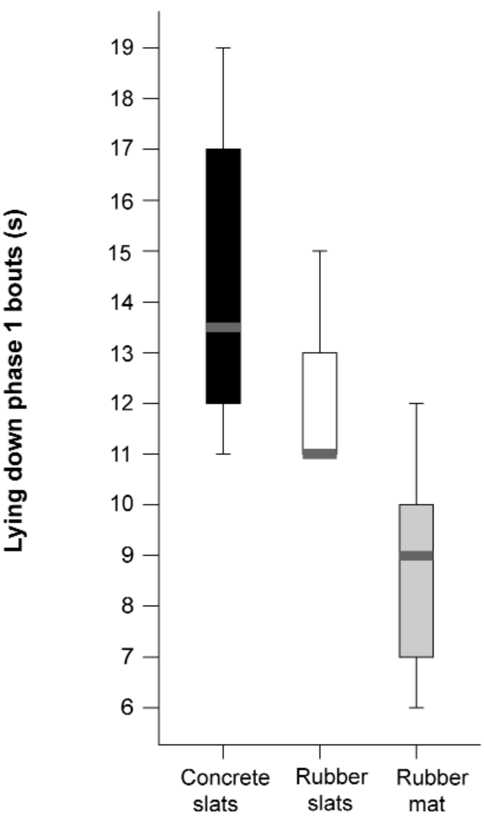
During observations, 14 animals (or 17.5% of the bulls in the experiment) were seen to tongue-roll with the longest bout lasting for 17 min. Nine of the tongue-rolling bulls were in pens with CS, three in pens with RS and two in pens with RM. One bull on CS was observed to press his nose against the water bowl on two occasions, for 2.5 and 3 min, respectively.

Figure 4



Mean (± SEM) number of interrupted attempts at lying down per 12 h on the three floor types for three different weight classes. *** $P < 0.01$; ** $P < 0.05$ * $0.05 < P < 0.1$.

Figure 5



Median duration (s) per pen of lying down phase 1 on the three floor types; dark grey line, boxes and bars represent median, 5th, 25th, 75th and 95th percentiles, respectively.

Claw and leg disorders

The prevalence of claw and leg disorders, presented as a maximal score obtained from the two examinations, stratified by treatment, can be seen in Table 2. Severe sole lesions and white line haemorrhages were found in bulls on CS only and these disorders were also most prevalent on CS and least on RM. Dermatitis was observed in most bulls on all floor types, but on CS more bulls had severe dermatitis than on both rubber floors. Conversely, fewer bulls on CS had heel horn erosion than on RS and RM.

Bulls kept in pens with CS generally had more frequent and more severe leg injuries. Every single animal on CS developed swelling, with 68% exhibiting severe swelling. Hairlessness was less common and less severe in pens with rubber flooring, the proportion of animals with skin damage of joints was small and no bull had severe skin damage (Table 2).

Of all bulls taking part in both examinations (n = 62), there were nine (14.5%) with no leg disorders, seven on RM and two on RS. Every single bull had at least one claw disorder, which means that most bulls in the experiment had multiple claw and leg disorders, often on more than one leg.

The results of testing the floor type effect on summarised weighted scores of claw and leg disorders are presented in Table 2. The score for sole haemorrhage was significantly lower on RM than on CS. The summarised score for white line haemorrhage in bulls on CS was significantly higher than on both RM and RS (Table 2). There was no difference in the scores for sole and white line haemorrhage between RS and RM (Table 2). The score for heel horn erosion was

Table 2 Mean (± SEM) and prevalence of summarised weighted ($2^{[severity - 1]}$) scores for claw and leg lesions and comparisons of the summarised weighted scores across the different floor types (Tukey's adjustment).

Lesion[1]	Floor[2]	Prevalence of each severity degree (%)[3]			Mean (± SEM) of adjusted scores sum	the compared floor types	*P*-value
		1	2	3			
SH	CS	12	68	20	10.44 (± 0.41)	CS–RM	< 0.05
	RS	20	80	0	9.40 (± 0.45)	CS–RS	ns
	RM	40	60	0	8.87 (± 0.45)	RM–RS	ns
WLH	CS	12	64	24	9.45 (± 0.15)	CS–RM	< 0.001
	RS	40	60	0	8.55 (± 0.17)	CS–RS	< 0.01
	RM	70	30	0	8.17 (± 0.17)	RM–RS	ns
HE	CS	56	40	4	8.44 (± 0.27)	CS–RM	< 0.01
	RS	5	70	25	10.72 (± 0.30)	CS–RS	< 0.001
	RM	15	60	25	10.32 (± 0.30)	RM–RS	ns
D	CS	12	44	44	6.17 (± 0.35)	CS–RM	ns
	RS	5	70	25	6.22 (± 0.38)	CS–RS	ns
	RM	20	60	20	5.47 (± 0.38)	RM–RS	ns
H	CS	32	48	20	4.93 (± 0.20)	CS–RM	ns
	RS	75	10	15	4.40 (± 0.22)	CS–RS	ns
	RM	55	40	5	4.27 (± 0.22)	RM–RS	ns
SD	CS	72	28	0	4.14 (± 0.04)	CS–RM	ns
	RS	90	10	0	4.05 (± 0.04)	CS–RS	ns
	RM	95	5	0	4.02 (± 0.04)	RM–RS	ns
S	CS	0	32	68	8.46 (± 0.41)	CS–RM	< 0.001
	RS	20	65	15	5.05 (± 0.45)	CS–RS	< 0.001
	RM	50	35	15	4.55 (± 0.45)	RM–RS	ns

[1] SH: sole haemorrhage; WLH: white line haemorrhage; HE: heel horn erosion; D: dermatitis; H: hairlessness; SD: skin damage; S: swelling on tarsus and carpus.
[2] CS: concrete slats; RS: rubber slats; RM: slotted rubber mats.
[3] Prevalence of claw and leg lesions presented as maximum individual value from the two examinations, 1: no lesion; 2: slight lesion; 3: severe lesion.

significantly higher on both rubber floors than on CS (Table 2). No significant effect of floor type was found for dermatitis (Table 2). We did not observe any effect of the studied floor types on skin damage and hairlessness. Both RS and RM were characterised by a significantly lower score for swelling than on CS (Table 2). Effect of weight class was significant for heel horn erosion ($F = 74.65$, df = 1, $P < 0.001$), white line haemorrhages ($F = 5.32$, df = 1, $P < 0.05$), dermatitis ($F = 30.45$, df = 1, $P < 0.001$) and hairlessness ($F = 5.99$, df = 1, $P < 0.05$) where the scores for these lesions were higher with higher weight.

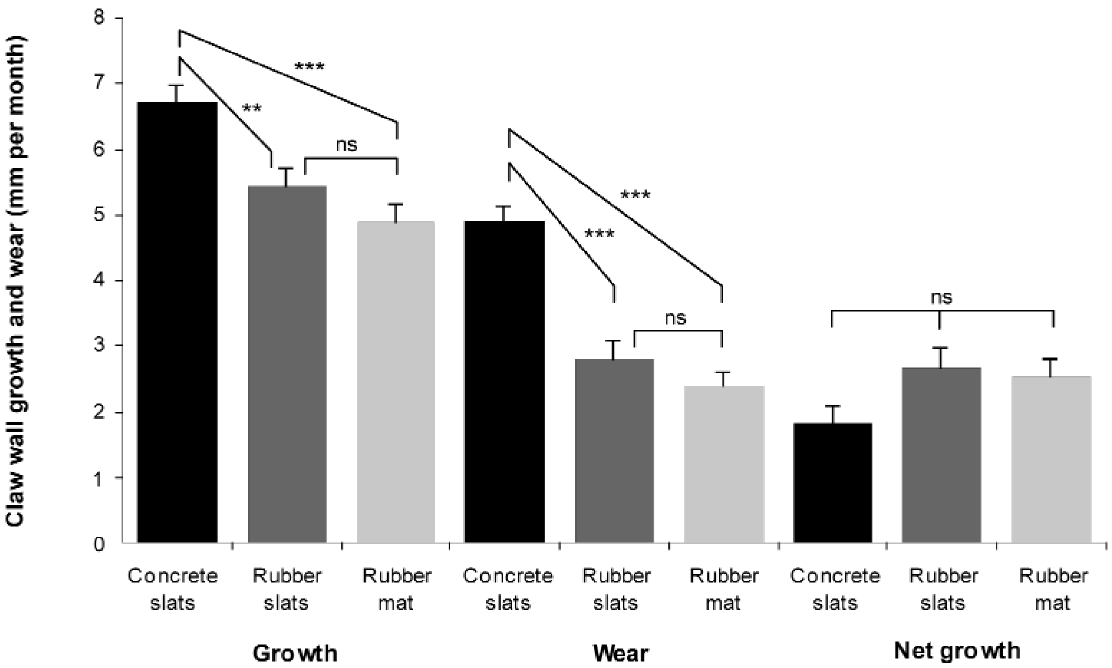
Claw horn growth and wear rate

There was no significant difference in claw horn growth and wear rate between RS and RM. Both claw horn growth and wear rate were significantly higher in bulls on CS than in bulls on both rubber floors (Figure 6). Net growth did not differ across the different floor types.

Cleanliness

Bulls housed on CS (15.4 [± 0.8] and RS (12.6 [± 0.9]) were cleaner ($P < 0.05$ and $P < 0.001$, respectively) than bulls on RM (19.5 [± 0.9]). No statistical difference was found between animals on CS and RS. Irrespective of floor type, 'Rear' was the dirtiest (17.6 [± 0.6]) and 'Front' the cleanest (13.8 [± 0.6]) among the body parts ($P < 0.001$). At the first recording, median cleanliness scores were 2 for 'Front' (Q1 = 1, Q3 = 2), 2 for 'Belly' (Q1 = 2, Q3 = 3) and 3 for 'Rear' (Q1 = 2, Q3 = 3). At the last recording, median scores were 1 for 'Front' (Q1 = 1, Q3 = 2), 2 for 'Belly' (Q1 = 1, Q3 = 2) and 2 for 'Rear' (Q1 = 1, Q3 = 2). No interaction between floor type and body part was found. No bull at slaughter had a deduction in carcase payments due to cleanliness below the acceptable limit (Anonymous 2008).

Figure 6



Least square means (± SEM) of claw horn growth, wear and net growth (growth–wear) in mm per month in growing bulls on the three floor types. *** $P < 0.001$; ** $P < 0.01$.

Table 3 Least square means (± SEM) of daily dry matter (DM) intake, metabolisable energy (ME) intake, feed efficiency (FE; n = 5 for RS and RM, n = 6 for CS) and average daily liveweight gain (ADG; n = 19 for RS, n = 20 for RM, n = 24 for CS) for dairy bulls during the periods from 225 to 400 kg and from 225 to 650 kg average liveweight.

	225 to 400 kg				225 to 650 kg			
	Concrete slats (CS)	Rubber slats (RS)	Rubber mats (RM)	*P*-value	Concrete slats (CS)	Rubber slats (RS)	Rubber mats (RM)	*P*-value
DM intake (kg DM)	7.07 (± 0.08)	7.31 (± 0.09)	7.28 (± 0.09)	ns	8.84 (± 0.12)	9.14 (± 0.13)	9.12 (± 0.13)	ns
ME intake (MJ)	78 (± 1)	90 (± 1)	89 (± 1)	ns	109 (± 2)	112 (± 2)	112 (± 2)	ns
FE (g gain kg^{-1} SM)	186 (± 4)	197 (± 4)	198 (± 4)	0.096	135 (± 5)	141 (± 6)	146 (± 6)	ns
FE (g gain MJ^{-1} ME)	15.2 (± 0.3)	160 (± 0.3)	16.2 (± 0.3)	0.085	11.0 (± 0.4)	11.4 (± 0.5)	11.9 (± 0.5)	ns
ADG (kg)	1.43 (± 0.03)[a]	1.56 (± 0.03)[b]	1.51 (± 0.03)[ab]	< 0.05	1.33 (± 0.02)	1.43 (± 0.02)	1.43 (± 0.02)	ns

Different supercripts within rows mark significant differences at $P < 0.05$.

Production parameters

No differences in daily DM and ME intake were found between the floor types (Table 3). During the period of liveweight gain from 225 to 400 kg, there was a significant effect of floor type, with bulls on CS having lower ADG than bulls on RS ($F = 4.55$, df = 15, $P < 0.05$; Table 3). In addition, feed conversion efficiency tended to differ between floor types (Table 3). During the period of liveweight gain from 400 to 650 kg, average daily DM intake was 9.68 kg, ME intake was 119 MJ and ADG was 1.33 kg. No differences in any production parameter between the floor types was observed in this period or averaged over the entire experimental period from 225 to 650 kg (Table 3). However, there was a tendency ($P = 0.060$) to differing slaughter ages where average slaughter ages were 541, 520 and 510 days for bulls on CS, RS and RM, respectively.

Different superscripts within rows mark significant differences at $P < 0.05$.

Average carcase measurements were 348 kg for carcase weight, 52.4% for dressing-out, score 4.8 for conformation and score 8.3 for fatness. With the exception of a tendency for differing conformation scores (4.3 for CS, 5.0 for RS and 5.0 for CS; $P = 0.072$) no effect of floor type on carcase measurements was observed.

Discussion

The space and comfort in confined housing systems are not at all comparable with the situation for animals on pasture. Some loose housing systems can provide the animals with satisfactory space and a soft lying area (Livesey *et al* 2002). However, in fully slatted floor pen housing, lying and standing comfort is compromised and animals can rarely express normal behaviour, although this is an easy system to manage and animals are kept satisfactorily clean (Scott & Kelly 1989).

In this study, we found equal total lying times per 12 h on all floor types, but growing bulls on the softest of the three floor types tested had the shortest lying bouts and the highest lying frequency during the beginning of the rearing time. This confirms findings by Ruis-Heutinck *et al* (2000), Platz *et al* (2007), Zerbe *et al* (2008) and Absmanner *et al* (2009). As suggested by Ruis-Heutinck *et al* (2000), the hard surface may hurt to such an extent during the lying down and standing up movement that this influences the behaviour of the bulls. The higher frequency of interrupted attempts at lying down on the concrete floor in comparison to the rubber floors, which is in agreement with other studies (Ruis-Heutinck *et al* 2000; Gygax *et al* 2007a), further indicates that it is uncomfortable or even painful to lie down on concrete. Studies have shown that swelling and skin damage become more prevalent with increasing floor hardness (Ruis-Heutinck *et al* 2000; Platz *et al* 2007; Schulze Westerath *et al* 2007; Zerbe *et al* 2008). In this study, we found more swellings in animals kept on concrete slats than in those on both types of rubber floors. Animals with leg swelling, especially severe swelling, are likely to experience pain during lying down and standing up, which may further impair lying behaviour, creating a vicious cycle. Zerbe *et al* (2008) compared the number of interrupted attempts at lying down or standing up, which were referred to as abnormal, with the number of successful lying down and standing up movements and found that only 50% of lying down and standing up movements on concrete slats were normal, compared with 80% on rubber mats. The corresponding values found in this study for concrete slats and rubber mats are in agreement with those results. Dairy cows are reported to have a shorter lying down phase 1 when they have a softer lying surface (Krohn & Munksgaard 1993). This is in agreement with our finding of the shortest phase 1 in bulls on the rubber mats.

The lower scores for sole and white line haemorrhage on rubber mats in comparison to concrete slats is in accordance with findings reported for dairy cows, where animals on slotted rubber mats had fewer sole and white line haemorrhage than cows on concrete slats (Bergsten *et al* 2009). The higher score for heel horn erosion on RM can be explained by the smaller drainage capacity of that floor, but significantly higher heel horn erosion score on RS compared with concrete slats in the present study is somewhat confusing. Heel horn erosion has been shown to be correlated with poor hygienic conditions of floor and claws (Bergsten & Pettersson 1992; Hultgren & Bergsten 2001; Manske *et al* 2002). An explanation for the lower prevalence of heel horn erosion on concrete slats could be the lower horn growth and wear on rubber flooring, conserving eroded horn for a longer time. Similarly, in a study by Bergsten *et al* (2009), heifers kept on less-wearing deep straw bedding were reported to have a higher prevalence of heel horn erosion than those in cubicle systems with more wearing concrete alleys, although animals in cubicles had more dermatitis. Dermatitis is usually associated with heel horn erosion (Manske *et al* 2002; Bergsten *et al* 2009), but in the present study, the score for dermatitis in bulls on rubber-covered floors did not differ from those on concrete slats. Despite the overall high prevalence of claw lesions, only a few of these could be regarded as causing discomfort or pain. Studies have shown that even when using very sensitive kinematic gait analysis, no difference in locomotion can be found between cows with and without sole haemorrhage (Flower *et al* 2005).

The prevalence of carpal (front knee) and tarsal (hock) injuries is usually related to the exposure of the protruding skeleton to hard, abrasive flooring in combination with restricted space, and the lesions usually do not involve the inside of the joint. Swelling inside the hock joint can be an expression of a cartilage disease not associated with traumatic lesions when lying (Persson *et al* 2007), but possibly when the animal is standing. Irrespective of type, rubber floors resulted in a lower score for swelling in the present study. As no difference in the total lying time per 12 h was observed, the leg lesions were a pure effect of the softer flooring *per se*. Although not significant, less hairlessness and less skin damage on rubber floors was also in agreement with earlier studies, as these lesions are less prevalent on a softer lying surface (Livesey *et al* 2002; Rutherford *et al* 2008).

One possible problem with softer flooring could be less wear from less abrasive flooring, as reported by Zerbe *et al* (2008) and Bergsten *et al* (2009). However, the lower wear rate on rubber for the Swedish Holstein bulls in our study was compensated physiologically by lower claw horn growth, which is in agreement with earlier studies on dairy cows (Telezhenko *et al* 2009). The different abrasive characters of the concrete floors could explain the differing results between our study and those of Zerbe *et al* (2008) and Bergsten *et al* (2009). The concrete floor in our study was 30 years old and hence rather smooth, while the concrete floors in the other studies might have been newer and therefore more abrasive.

In our study, the cleanliness of the animals was generally satisfactory. The rubber mats had a smaller drainage area (14%) than the concrete slats (21%), which resulted in dirtier animals. Lowe *et al* (2001) did not find a difference in cleanliness between concrete slats and rubber mats. However, the difference between their drainage area was smaller (23.5% for concrete and 19% for rubber mats) and the drainage area was greater than in our study. Lenehan (2003) found cleaner animals on rubber mats than on concrete slats, whereas Schulze Westerath *et al* (2007) did not find any difference, but neither of these studies reported whether there was any difference in drainage area. In many countries, elements of a number of slats and slots are used, so there is very little or no difference in drainage area between concrete slats and rubber mats, unlike in, eg Sweden, where single concrete slats are used and a larger rubber mat construction is required. A larger drainage area improves the drainage capacity but also gives a more uncomfortable and less secure floor for the animals, exemplifying the compromise needed between these factors. Finding an optimal slot and slat width combination for slotted rubber mats without reducing the drainage area would reduce the risk of dirtier animals. Another possibility to achieve cleaner animals could be scrapers on top of the floor. Alternatively, Gygax *et al* (2007b) and Zerbe *et al* (2008) showed that more space per animal resulted in cleaner animals.

The lower average slaughter age observed in the present study for bulls on rubber floors compared with those on concrete slats derived from a higher liveweight gain in the former during the first period of the experiment, from 225 to 400 kg. This improved performance on the rubber floors compared with the concrete floor during the first liveweight gain period was not repeated during the second period, from 400 to 650 kg average liveweight, possibly due to the increasing liveweight. The wide slots between slats (38 mm) on the concrete floor in combination with the higher drainage area were probably more uncomfortable for young calves with small claws than for older animals. Furthermore, the difference between housing in the pre-experiment deep straw bedding and the experimental pens was probably larger for the bull calves moved to the concrete floor than for those on rubber mats. The combination of these two circumstances might explain the difference between the floor types in the first but not the second liveweight gain period. Ruis-Heutinck *et al* (2000) and Lowe *et al* (2001) did not find any effects of floor type on weight gain, although the initial liveweight of calves in the study by Ruis-Heutinck *et al* (2000) was as low as in the present study. The tendency to lower carcase conformation score in bulls on concrete in the present study might be a random effect as no effect of floor type on carcase conformation has been found in previous studies (Ruis-Heutinck *et al* 2000; Lowe *et al* 2001). Mossberg *et al* (1993) compared concrete pens, similar to those used in the present study, with deep-straw bedding pens, with regards to performance in dairy bulls, and did not find any effect

Animal welfare implications and conclusion

Equipping slatted concrete floors with rubber improves animal welfare in terms of decreasing the number of interrupted attempts at lying down, increasing the lying frequency, and diminishing the occurrence of swelling, sole and white line haemorrhages with maintained net claw horn growth. In addition, the overall rearing time tended to be shorter on rubber flooring. However, the risk of heel horn erosion increased on rubber floors, while rubber mats with less drainage area resulted in dirtier animals.

To improve animal welfare, the floor in fully slatted pens should be covered with rubber. However, even on the fully slatted floor system with rubber flooring, tested in this study, animals suffered injuries and were prevented from exhibiting natural behaviours, so this floor does not fulfil the 'Five Freedoms' of animal welfare (Farm Animal Welfare Council 1979). To further improve welfare in intensive rearing systems, new solutions that fulfil these Five Freedoms must be developed and implemented.

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