Changes in hoof health and animal hygiene in a dairy herd after covering concrete slatted floor with slatted rubber mats: A case study

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ABSTRACT

The objective was to investigate the effect of changing the flooring in the alleys of a barn from slatted concrete to slatted rubber mats on hoof disorders and animal hygiene in 44 loose-housed Brown Swiss dairy cows. Cows were examined for disorders of the hind hooves (hemorrhages, white line fissures, ulcers, heel horn erosion, and digital dermatitis) and for skin lesions. The dirtiness of the animals and of the floor was recorded. Climatic (temperature, humidity) and ammonia gas conditions were measured. Evaluations were carried out when the cows were housed on a concrete slatted floor and after 4 and 10 mo on soft flooring (slatted rubber mats, 29-mm thick). The anatomical portion of claw (medial, lateral), number of lactations (parity), and days in milk were included as covariates in the statistical model. Changing the flooring from slatted concrete to slatted rubber mats increased the score for white line fissures [1.0 ± 0.3 (concrete) vs. 2.5 ± 0.4 (10 mo rubber mats)] and influenced air humidity (i.e., the difference in the absolute humidity between the inside and outside of the barn increased from 1.5 ± 0.1 to 1.7 ± 0.2 g/m^3), whereas the other hoof disorders, skin lesions (score of 8.7 ± 0.3), the dirtiness of the animals (score of 5.9 ± 0.3), and the floor (score of 2.1 ± 0.1), and ammonia gas concentration (2.6 ± 0.3 mg/kg) were not affected (overall scores or measures; mean $\pm$ SE). Lateral claws were more affected (except for heel horn erosion) than medial claws (estimated effects between 1.3 ± 0.2 and 3.0 ± 0.6). Parity influenced hoof disorders (except for hemorrhages) and skin lesions (estimated effects between -0.6 ± 0.3 and 0.5 ± 0.2). Days in milk influenced hoof disorders, but had no effect on skin lesions and on the dirtiness of the animal. Irrespective of floor type, the slots (2.6 ± 0.1) were dirtier than the slats (1.6 ± 0.1). In conclusion, covering slatted concrete flooring with slatted rubber mats partially impaired hoof health but did not influence skin lesions or the dirtiness of the cows or the floor. Similar results were found for climatic conditions, as ammonia gas concentration was not affected, but absolute humidity increased in the barn when rubber mats were present.

Key words: dairy cattle, flooring, hoof health, animal hygiene

INTRODUCTION

Improving the flooring in dairy cattle housing is of interest because lameness, which is associated with concrete flooring, is a major economic and welfare issue (Cook et al., 2004). Whereas soft flooring is associated with signs of enhanced welfare and improved locomotion behavior in dairy cattle (Fregonesi et al., 2002; Platz et al., 2008), its effect on hoof health is controversial. Although Benz and Wandel (2004) reported improvements in the hoof health in general, Vokey et al. (2001) and Vanegas et al. (2006) failed to confirm these benefits. Kremer et al. (2007) reported that elastic flooring does not necessarily improve hoof health with respect to the disorders evaluated (digital dermatitis, heel erosion, sole ulcer, sole hemorrhages, and hyperplasia interdigitalis).

The discrepancies between concrete and rubber slats may arise from a difference in claw compression due to the decreased wear of the hoof on soft flooring. Telezhenko et al. (2008) reported that on smoother floors the weight of the animal rests mostly on the bulbar and wall segments of the claw, whereas on more abrasive flooring, increased weight bearing on the sole and a lower average pressure on the claw occurs. Rubber flooring provides more secure footing and is more comfortable for lame cows to walk on (Flower et al., 2007). Irrespective of the floor type, the lateral claws are more exposed to biomechanical load due to the greater length of the lateral digit (Nuss and Paulus, 2006), resulting in a higher susceptibility to disorders (Vanegas et al., 2006).

Changing flooring has an effect, not only on hoof health, but also on animal hygiene, as the dirtiness of the floor and of the cows changes due to the altered manure drainage. Research regarding the hygienic conditions and the efficiency of manure drainage from floors covered with slatted rubber mats is limited. Bulls kept on slatted rubber mats were significantly dirtier than bulls kept on other surfaces (Lowe et al., 2001). In contrast, Benz (2002) stated that the self-cleaning function of the slatted floor is unimpeded by slatted rubber mats or even improved due to the higher activity of the cows in dairy cattle housing. Cleaner floor conditions should result in cleaner cows, decreasing the risk of mastitis and improving milk quality (Schreiner and Ruegg, 2003). But, exactly the opposite could be expected if the soft flooring increases the number of observations of the behavior "resting in the alley" (Platz et al., 2008).

Due to the higher activity of cows on soft flooring, shown by an increased number of steps, increased mounting and altered resting behavior (Platz et al., 2008), a change in the incidence of skin lesions cannot be excluded. Moreover, in association with the hygienic conditions of the floor, climatic and ammonia gas conditions could be affected. These conditions, measured in the barn environment, may be highly informative because humidity and the concentration of ammonia may yield information regarding floor wetness, dirtiness, and microbial activity, which, in turn, influence hoof health.

Therefore, alongside observations on cow behavior (Platz et al., 2008), measurements of hoof disorders, skin lesions, the dirtiness of the cows and the floor, as well as climatic and ammonia gas conditions were conducted before and after a change from slatted concrete to slatted rubber mats.

MATERIALS AND METHODS

Design of the Study

The study was designed as a single-system study (i.e., the effect of the slatted rubber mats in one herd). The study was divided into 3 phases, in which phase 1 (October to February) represented the period when the cows were housed on the slatted concrete floor and phases 2 (March to June) and 3 (July to December) represented periods when the cows were housed on slatted rubber mats.

Animals

The study was conducted on a dairy herd of 50 Brown Swiss cows (dual-purpose breed, estimated BW 600 to 700 kg) kept in freestall housing at the Dairy Cattle

Experimental Farm of the Technical University of Munich/Freising-Weihenstephan, Germany. Forty-four cows took part in all investigations and were included in analyses. The milk yield was $8{,}939 \pm 1{,}404$ kg (true protein $3.61 \pm 0.20\%$ and milk fat $4.36 \pm 0.29\%$; mean $\pm$ SD). At the beginning of the study, the cows differed in age (between 3 and 8 yr, 4.8 ± 0.2 yr; mean $\pm$ SE), in the number of lactations (parities; between 0 and 4, 1.4 ± 0.2), and in the stages of lactation (DIM between 10 and 629, 182 ± 28 d; n = 33; 11 dry cows). The cows were fed an enriched mixed ration of 2/3 corn silage and 1/3 grass silage + concentrates adapted to a milk yield of 22 kg. More highly productive cows were automatically (i.e., by transponder) supplemented with 500 g of concentrates per kilogram of milk yielded in excess of 22 kg. In the event of calving (which applied to 21 cows), the cows were separated into a straw-bedded maternity pen within the barn for about 24 h before parturition to 24 h postpartum.

Flooring

The slatted rubber mats (Type Kura S; Gummiwerke Kraiburg, Tittmoning, Germany) were installed in the alleys after phase 1. They can be fabricated to correspond to the slatted floor elements in any desired dimensions. The mats were 29-mm thick (including 5 mm of rubber nubs on the undersurface) and the upper side was hammer-blow-profiled to enhance grip. A technical report by Reubold (2004) reported a penetration depth of 3.8 mm of a steel foot at a force of 2,000 N. Slip resistance was described as good at a speed of 20 mm/s on both dry and wet surfaces. The edges were profiled to permit grooveless laying.

Housing Environment

The barn had a central feeding alley with feeding managers and 4 rows of freestalls, 2 on either side of the feeding alley, arranged in a tail-to-tail configuration. Both sides of the feeding alley were connected by a walkway leading up to the milking parlor. The stalls were bedded with straw. The thickness of the straw bedding varied from 0 to 20 cm due to the presence of a rubber mattress on the floor of the stall, which, in some freestalls, prevented a uniform texture of the straw bedding. Every 10 to 14 d the stalls were replenished. The dimensions of the freestalls were 115 cm in width, 200 cm in bed length, 44 cm of forward lunge space, and a neck rail height of 108 cm.

Assessment of Hoof Disorders

Hoof disorders were assessed in the presence of a professional claw trimmer during regular claw trimming,

Table 1. Classification of pathological findings in the scoring system applied to hoof disorders

Disorder	Score 1	Score 2	Score 3	Score 4	Score 5
Hemorrhage	Slight horn discoloration, few petechial bleedings	Yellow horn discoloration 5 to 10 mm, many petechial bleedings	Red discoloration >10 mm, many petechial bleedings	Red discoloration on >half of the affected location	Intensive red coloration throughout the affected location
Ulcer	Necrotic horn without dissected corium, size <5 mm	Necrotic horn with dissected corium, size <5 mm	Necrotic horn with dissected, unproliferated corium, size 5 to 10 mm	Necrotic horn with dissected and proliferated corium, size >10 mm	Deep located inflammation, complicated ulcer
White line fissure	Length <5 mm, superficial	Length 5 to 10 mm, depth <3 mm	Length 5 to 10 mm, depth >3 mm	Length 10 to 20 mm, depth >3 mm	Length >20 mm, depth >3 mm
Heel horn erosion	<5 mm, superficial	5 to 10 mm, depth <3 mm	Groove formation, depth >3 mm	Distinct groove formation, severe horn damage, little undermining of the horn	Inflammation, damage of horn to very large degree, large area of undermined horn
Digital dermatitis	<5 mm, superficial, indolent	5 to 10 mm, upright directed hairs	>10 mm, reddened, sensitive	>20 mm, highly reddened and painful	>20 mm, inflamed, deep alteration

which took place every 4 to 6 mo. Assessment was first conducted when the cows were housed on concrete slats, 3 d before starting floor replacement (end of phase 1: February). The following 2 assessments took place after 4 (end of phase 2: June) and 10 mo, respectively, on soft flooring (end of phase 3: December). Evaluations involved the lateral and medial claws of both hind limbs. First, the claw was washed and the plantar surface was pared superficially. The following locations were evaluated: axial and abaxial wall, white line, sole, claw tip, Rusterholz location (region of the sole-bulb junction of the lateral claw, near to the axial margin), heel, and interdigital space. The severity of hemorrhages (including claw tip, white line, sole, and Rusterholz location), white line fissures, ulcers (including abaxial wall, claw tip, sole, and Rusterholz location), heel horn erosions, and digital dermatitis was classified using a score described by Benz (2002; Table 1). In brief, the findings were scored on a scale from 0 (no abnormalities) to 5 (severe). In the event of disorders that required therapy, the cows were treated locally according to the findings [e.g., adhering blocks of wood or plastic to the bottom of the healthy or unaffected claws or topical application of an antibiotic spray containing chlortetracycline (CTC Spray; Novartis, Munich, Germany), in the case of digital dermatitis].

Assessment of Skin Lesions

At the same time as hoof evaluations took place, assessment of skin lesions on the back (withers, thoracic spine, and lumbar spine), the phalanx proximalis of the fore limbs, and at the carpal and tarsal joints was conducted and scored as 0 (no abnormalities), 1 (area of thinned hair), 2 (hairless area), 3 (hairless and thick-ened skin), and 4 (thickened skin with scabs, blood, or secretion).

Assessment of the Dirtiness of the Animal

To assess the dirtiness of the animal, the phalanx proximalis of the hind limbs, the tarsal joint, the lower leg, the thigh-trunk-udder-region, and the fore limb of both the left and the right side of the cows, as well as the anal region and the upper, middle, and lower third of the tail were evaluated separately. Each of these 14 sites was defined as dirty (score = 1) or not dirty (score = 0), depending on whether an area of feces of greater or at least equal to the palm of the hand (approximately 8 × 8 cm) was present or not. All scores were summed to obtain a total score for each animal (between 0 and 14).

Assessment of the Dirtiness of the Floor

The floor was manually cleaned daily at 0700 and 1600 h by moving the manure with a scraper from the rear curb of the stalls to the more frequented middle section of the alleys. The slats on the floor were grouped into elements consisting of 20 to 23 slats (each 8-cm wide) and 19 to 22 slots (each 3-cm wide). The percentage of the perforated floor area through which waste and urine could pass was 9.6% of each element. Assessment of the dirtiness of the floor took place between 1200 and 1300 h and was carried out on 6 floor elements, each from the middle range of the existing 6 alleys. The slats and slots of these elements were scored based on the percentage of dirt (layer of feces >1 cm), as described by Reubold (2004): 1 = 0 to 25% dirty, 2 = 26 to 50% dirty, 3 = 51 to 75% dirty, and 4 = 76 to 100%

Table 2. Approximations for calculating the saturated air humidity

Scope of application	Equation [s (t)][1]
$-20 < t < 3.2144°C$	$s = 4.6962 \times e^{0.0788 \times t}$
$3.2144 \leq t < 26.2313°C$	$s = 4.952 \times e^{0.0623 \times t}$
$26.2313 \leq t < 50°C$	$s = 6.784 \times e^{0.0503 \times t}$

[1]s (t) = saturated air humidity (g/m^3) at the temperature (t) (Praxl, 2006).

dirty. The 6 floor elements were evaluated at weekly intervals for 10 wk within each period of investigation. To avoid the interference of adjacent elements by slat-to-slat configurations, the first slat and slot of each side of a floor element were excluded from evaluation. The score for the slats and slots was calculated from the mean value of the individual evaluations of slots (n = 17 to 20) and slats (n = 18 to 21) of each element and repetitions (n = 10 wk) in each period of investigation (beginning of phase 1, end of phase 2 and 3).

Climatic and Ammonia Gas Conditions

Climatic and ammonia gas conditions were measured at weekly intervals. At the same time of day, temperature and humidity were measured inside and outside the barn using an Almemo 2290 instrument in combination with an Almemo FH A646–1 temperature and humidity sensor (Ahlborn, Holzkirchen, Germany). For the assessment of ammonia gas in the barn, a Dräger MiniWarn multi-gas monitor (Dräger, Lübeck, Germany) was used. In the barn, variables were measured in the milking parlor and above the 6 floor elements mentioned above at a height of approximately 60 cm. From these measurements, a weekly mean was calculated for each variable. Differences in absolute humidity between the inside and outside of the barn were calculated by using the temperature in the approximations in Table 2 to obtain the saturated humidity. Thereafter, absolute humidity was calculated by means of the saturated and the relative humidity.

A statistical comparison of temperature, humidity, and ammonia gas was only meaningful for comparable seasons (i.e., October to December). Therefore, only the 10 wk of data collected during phase 1 and phase 3 were compared.

Statistical Analyses

The values of the scores for hemorrhages, white line fissures, ulcer, heel horn erosion, and skin lesions were compared among the phases using a generalized additive mixed model with Poisson distribution and the log-link. The anatomical portion of claw (medial, lateral) or site (phalanx proximalis of the fore limbs,

back, carpus, tarsus), parity, and DIM were included as covariates. Mixed models take into account the fact that the same animals are observed several times. Smooth effects for DIM were represented using penalized regression splines. A generalized additive or linear model with Poisson distribution can be used to model nonnegative variables with discrete support. In the case of overdispersion (this applied to the scores for digital dermatitis and the dirtiness of the animal), a quasi-Poisson approach with log-link was conducted. The covariates of these models were parity and DIM (due to the small number of positive scores for digital dermatitis, DIM could not be used as a nonlinear covariate in this model).

The distribution of the score for the dirtiness of the floor was symmetric and showed no outliers. As this variable had continuous support, a linear mixed model including site (slat, slot) as a covariate was used. For the same reason, an additive mixed model was chosen for analysis of the difference in absolute humidity inside and outside the barn. This model contained a smooth effect of calendar time to account for seasonal effects. The residuals of all models were inspected visually.

Comparison of temperature, humidity (both inside and outside the barn) and ammonia gas concentration (inside the barn) between phase 1 and phase 3 started with testing for normality (Kolmogorov-Smirnov test with the Lilliefors correction) and equal variance (Levene median test). If the data fulfilled the appropriate criteria (this applied to temperature and humidity), the student's unpaired *t*-test was used. If one test failed (this applied to ammonia gas concentration), the Mann-Whitney Rank Sum test was used.

Analyses of the models were performed using the freely available software program R, version 2.10.1 (R Development Core Team, 2010). For all other tests, SigmaPlot 11.1.0 (Systat, Erkrath, Germany) was used. Significance was defined as a probability value of $P < 0.05$.

RESULTS

Herd Characteristics

The number of dry cows at the hoof disorder assessments was 4, 3, and 7 cows for each phase, respectively. Between the assessment in phase 1 and 2, 6 cows gave birth to calves, whereas this applied to 15 cows between phase 2 and 3.

Hoof Disorders

Changing the floor from slatted concrete to slatted rubber mats increased the score for white line fissures (Figure 1B) after 10 mo on rubber mats ($P < 0.001$;
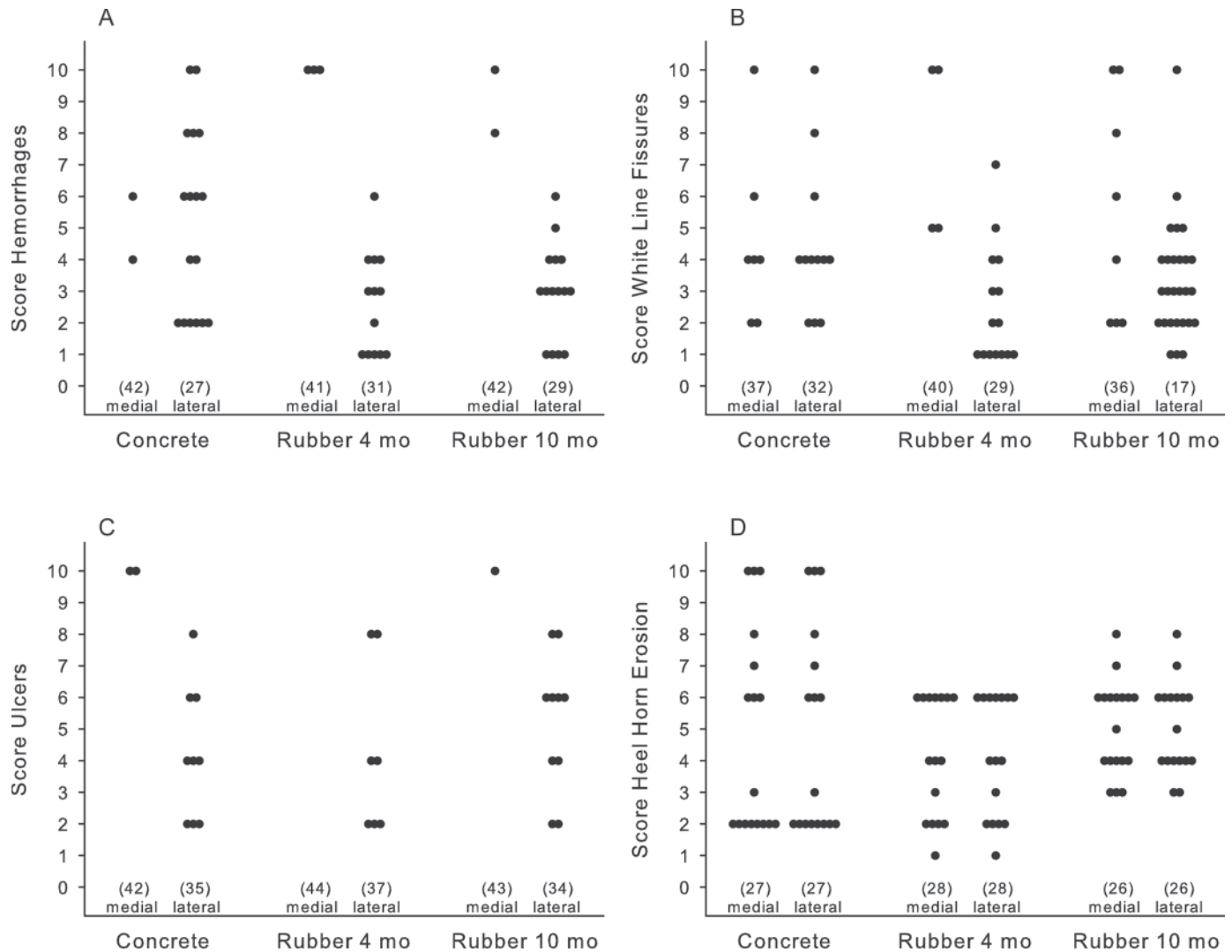
Figure 1. Scores for hoof disorders of the cows on concrete and after 4 and 10 mo on rubber mats. The assessment of hemorrhages (panel A), white line fissures (panel B), ulcers (panel C), and heel horn erosions (panel D) involved the medial and lateral claws of both hind limbs. Data represent the summation of both scores for the medial and lateral claws, respectively, of each cow. The number of cows in which no disorder was found (score = 0) is given in parentheses; n = 44.

Table 3), whereas the other hoof disorders (hemorrhages, ulcers, heel horn erosion, and digital dermatitis; Figures 1 and 2) were not affected. Parity significantly influenced the scores for white line fissures, ulcers, heel horn erosion, and digital dermatitis, whereas DIM influenced all hoof disorders, except digital dermatitis, for which the influence of DIM was not determined due to the small number of positive score values (Table 3). Compared with the medial claw, the lateral claw was more affected by hemorrhages, white line fissures, and ulcers ($P < 0.001$; Table 3).

Skin Lesions

Skin lesions were not influenced by changing the floor from slatted concrete to slatted rubber mats (Figure

3); however, parity significantly increased the score (Table 4). Compared with the phalanx proximalis of the fore limbs, the back had lower scores (estimated effect: -0.464 ± 0.104; $P < 0.001$), whereas the carpus (estimated effect: 1.069 ± 0.075; $P < 0.001$) and the tarsus (estimated effect: 0.979 ± 0.076; $P < 0.001$) had higher scores.

Dirtiness of the Animal

No difference was observed between the floor types regarding the dirtiness of the animal (Table 4; Figure 4). The most frequently affected sites were the phalanx proximalis of the hind limb (92%), followed by the lower third of the tail (81%), the tarsal joints (52%), the anal region (48%), the mid-third of the tail (33%),
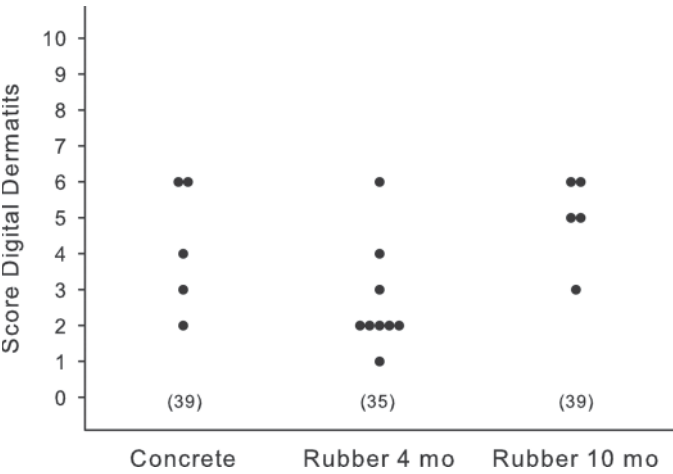
Figure 2. Scores for digital dermatitis of the cows on concrete and after 4 and 10 mo on rubber mats. The assessment involved both hind limbs. Data represent the summation of the scores of both hind limbs of each cow. The number of cows in which no digital dermatitis was found (score = 0) is given in parentheses; n = 44.

the lower leg of the hind limb (28%), the thigh-trunk-udder-region (25%), the fore limb (11%), and the upper third of the tail (10%; calculated from scores from all phases of the study). The DIM tended to have an influence on the dirtiness of the animal (Table 4).
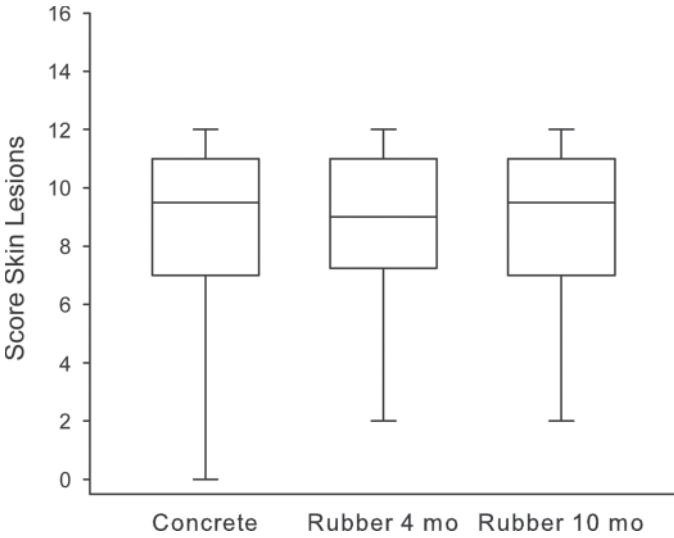
Figure 3. Scores for skin lesions of the cows on concrete and after 4 and 10 mo on rubber mats. The skin was evaluated on the back, the phalanx proximalis of the fore limbs, and at the carpal and tarsal joints of the cows, and scored on a scale from 0 to 4. All scores were summed (n = 44; median with 10-, 25-, 75-, and 90-percentiles).

Dirtiness of the Floor

The dirtiness of the floor did not differ between the 3 phases. Independently of the floor type, the slats

Table 3. Results from the generalized additive mixed model for the effect of fixed factors and for the nonlinear included effect of DIM on the score for hoof disorders[1]

Hoof disorder	Intercept	Rubber at 4 mo	Rubber at 10 mo	Parity	Lateral claw	DIM
		Fixed effect				Smooth term
Hemorrhage						
Estimated effect	−2.340	−0.272	0.285	0.034	1.979	
±SE	±0.429	±0.290	±0.284	±0.125	±0.316	
P-value	<0.001	0.349	0.316	0.785	<0.001	0.025
White line fissure						
Estimated effect	−2.092	0.099	0.964	0.200	1.253	
±SE	±0.362	±0.304	±0.256	±0.098	±0.236	
P-value	<0.001	0.744	<0.001	0.043	<0.001	0.029
Ulcer						
Estimated effect	−5.290	−0.459	−0.168	0.505	2.996	
±SE	±0.729	±0.323	±0.303	±0.189	±0.553	
P-value	<0.001	0.158	0.581	0.008	<0.001	0.004
Heel horn erosion						
Estimated effect	−0.782	0.103	−0.176	0.373	0.004	
±SE	±0.404	±0.198	±0.223	±0.172	±0.118	
P-value	0.054	0.603	0.431	0.031	0.972	<0.001
Digital dermatitis						
Estimated effect	−0.353	0.223	0.401	−0.583		
±SE	±0.528	±0.343	±0.352	±0.265		
P-value	0.505	0.518	0.258	0.030	ND[2]	ND[2]

[1]Table shows estimated effect with standard error and P-value. Parity is a metric covariate whose effect is assumed to be linear; lateral claw describes the effect of the lateral compared with the medial claw; DIM was included in the model as a smooth term, which means that a smooth function describing its effect was fitted, so no single value for the estimator can be given.
[2]Not determined.

Table 4. Results from the generalized additive mixed model for the effect of fixed factors and, if appropriate, for the nonlinear included effect of DIM on the score of skin lesions, and on the dirtiness of the animal and the floor[1]

Item	Intercept	Rubber at 4 mo	Rubber at 10 mo	Parity	Slots	DIM
			Fixed effect			Smooth term
Skin lesion						
Estimated effect	−0.259	−0.012	−0.062	0.161		
±SE	±0.167	±0.061	±0.068	±0.063		
P-value	0.121	0.848	0.366	0.010		0.175
Animal dirtiness						
Estimated effect	1.865	−0.064	0.039	−0.076		
±SE	±0.123	±0.069	±0.072	±0.052		
P-value	<0.001	0.359	0.588	0.141		0.077
Floor dirtiness						
Estimated effect	1.622	−0.025	−0.092		1.056	
±SE	±0.142	±0.157	±0.157		±0.128	
P-value	<0.001	0.874	0.563		<0.001	

[1]Table shows estimated effect with standard error and P-value. Parity is a metric covariate whose effect is assumed to be linear; slots describes the effect of slots compared with slats; DIM was included in the model as a smooth term, which means that a smooth function describing its effect was fitted, so no single value for the estimator can be given.

were significantly cleaner than the slots (Table 4; Figure 5).
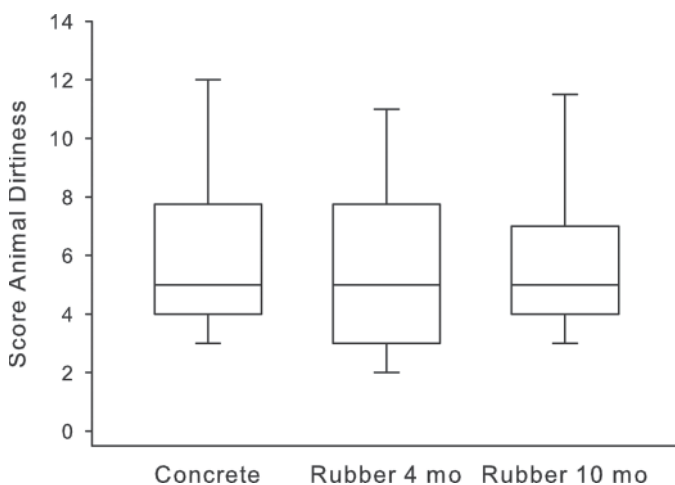
Climatic and Ammonia Gas Conditions

The climatic and ammonia gas conditions throughout the study are in Figure 6. Statistical comparison was conducted between phase 1 and phase 3 because data were collected in the same season. Consequently, outdoor temperature (phase 1 vs. 3: 8.7 ± 1.5 vs. 9.9 ± 2.1°C; P = 0.641) and outdoor humidity (phase 1 vs. 3: 67.3% ± 3.2% vs. 70.0% ± 3.0% relative humidity; P = 0.540) did not differ. In addition, no difference was found in the ammonia gas concentration in the barn

Figure 4. Dirtiness scores of the cows on concrete and after 4 and 10 mo on rubber mats. Fourteen regions of the cow were evaluated for dirt and scored as 0 (not dirty) or 1 (dirty). All scores were summed (n = 44; median with 10-, 25-, 75-, and 90-percentiles).

(phase 1 vs. 3: 4.1 ± 0.5 vs. 3.2 ± 0.8 mg/kg of NH_3; P = 0.198). Furthermore, climatic conditions inside the barn did not differ in terms of temperature and humidity (phase 1 vs. 3: 11.9 ± 1.0 vs. 12.6 ± 1.2°C; P = 0.642; and 69.8% ± 2.7% vs. 75.8% ± 2.7% relative humidity; P = 0.131; all data: mean ± SE, n = 10). The difference between the absolute humidity inside and outside the barn (which excluded temperature) was greater for the slatted rubber mats (difference for concrete: 1.48 ± 0.14 g/m³; for rubber mats: 1.71 ± 0.21 g/m³; estimated effect: 0.211 ± 0.094; P = 0.026).

DISCUSSION

In terms of hoof health, the present study revealed partial impairment due to covering concrete slats with slatted rubber mats. This supports research comparing the hoof health of cows on rubber floor matting and concrete flooring (Bell and Huxley, 2009; Rushen and de Passillé, 2009), in which no distinct benefits or disadvantages for hoof health of housing on a soft floor were observed.

In the present study, the score for white line fissures increased after a 10-mo stay on rubber mats (Figure 1B). White line fissures are caused by weakening of the white line and disturbances in horn production following laminitis (Ossent and Lischer, 1998; Mülling, 2002). This may be attributable to higher weight-bearing and (altered) shearing forces on the wall of the claw capsule (Telezhenko et al., 2008), as a result of the decreased wear of the claw horn on the rubber surface (Kremer et al., 2007). In general, the risk of white line fissures is increased on concrete slatted floors (when compared with solid concrete; Sogstad et al., 2005; Barker et al.,
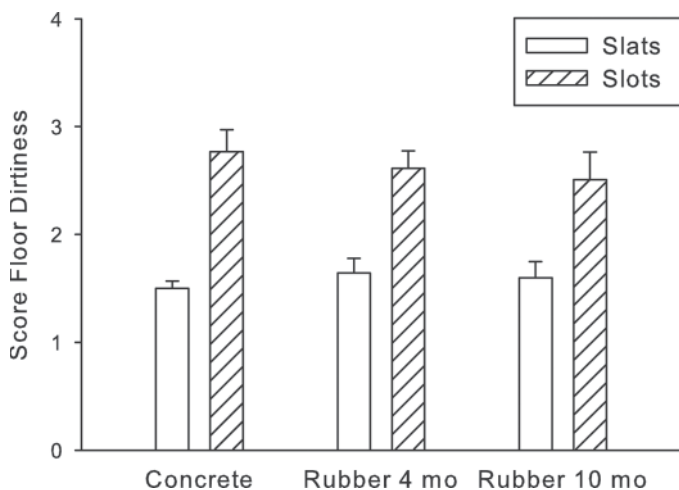
Figure 5. Scores for floor dirtiness when cows were on concrete and after 4 and 10 mo on rubber mats. Assessment of floor dirtiness was carried out on 6 floor elements. Slats and slots were rated using scores between 1 and 4. The score for the slats and slots of each element was calculated from the mean of all individual evaluations (17 to 21 slots and slats, respectively) and repetitions (10 wk) in each period of investigation (mean ± SE; n = 6).

2009), probably due to the uneven distribution of force within the claw capsule when the claw is only partially supported (Hinterhofer et al., 2006). This might be intensified on rubber slats due to the deformability of the rubber and the higher activity and mobility of the animals (Platz et al., 2008). It is noteworthy that trimming itself could be a risk for white line disease as the odds of a white line disease diagnosis was increased by an increased number of claw examinations (Kujala et al., 2010). This may be because a trimmer might take away too much of the supportive mechanism of the horn (Kujala et al., 2010) and, additionally, might expose immature horn in the white line (Manske et al., 2002).

The investigation on hoof disorders was restricted to the rear feet because most lesions are more prevalent in the hind than in the front hooves (Manske et al., 2002). Other predisposing factors are parity, location (lateral or medial claw), and DIM (Table 3). Supporting Sanders et al. (2009), parity increased the incidence of white line fissures, heel horn erosion, and ulcers, which could be interpreted as the consequence of long-lasting injurious effects on the claws that increase with age. The positive effect of parity on the incidence of digital dermatitis could be attributed to the development of limited immunity to the microorganisms that cause this disease (Laven and Logue, 2007).

Supporting Vanegas et al. (2006), the lateral claw of the hind foot was significantly more affected in the present study. This may be due to the anatomical difference in the length of the medial and lateral hind digits
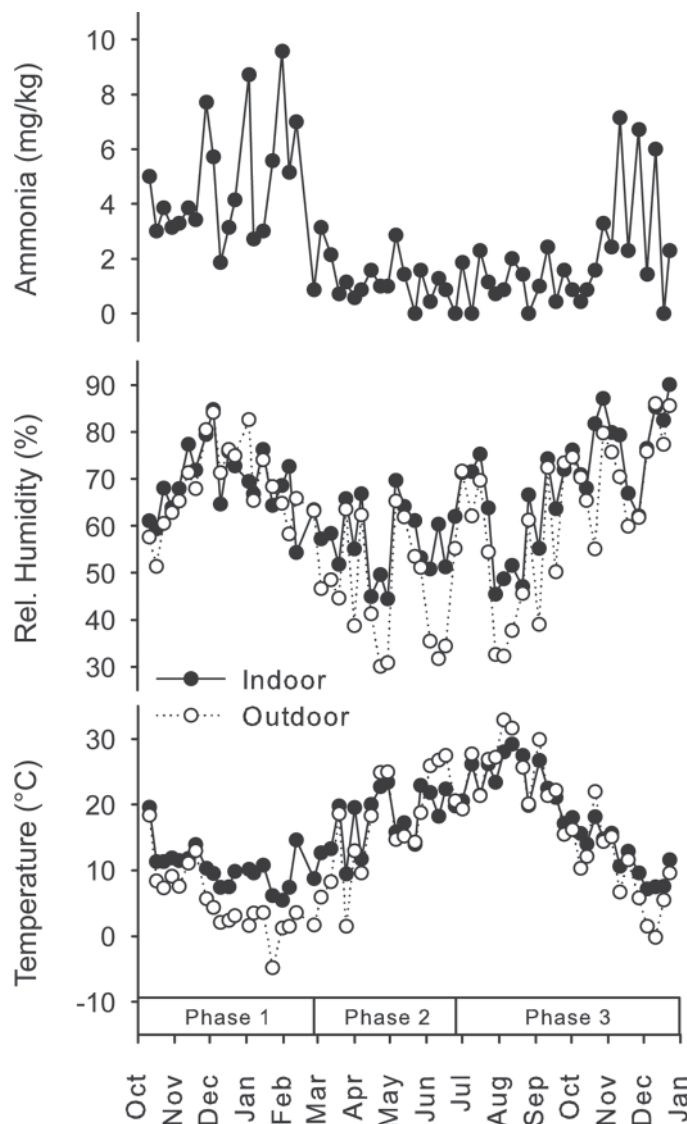
Figure 6. Climatic (temperature and relative humidity) and ammonia gas conditions during the study. Indoor values represent the mean of 7 measurements inside the barn.

(Nuss and Paulus, 2006), resulting in overloading of the lateral claw (van der Tol et al., 2003; Telezhenko et al., 2008). In contrast, disorders such as heel horn erosion and digital dermatitis more often result from increased floor moisture content, which affects both claws of the hind leg equally. In accordance to Capion et al. (2009) and Sanders et al. (2009), DIM, included as a nonlinear variable in our model, influenced the incidence of most of the hoof disorders in the present study (Table 3).

As a general health risk, skin lesions were included in our investigations due to the expected increase in activity and sexual behavior of the cows on rubber (Platz et al., 2008). The skin lesion score was high in the investigated barn, remained unchanged during

the study, and was significantly influenced by parity (Figure 3; Table 4). An association between skin lesions (i.e., hock lesions) and parity was reported by Rutherford et al. (2008) and Kielland et al. (2009). Skin lesions are mainly attributable to unfavorable stall conditions (Fulwider et al., 2007). Therefore, the lack of improvement in the stalls as well as the influence of the increased activity and mounting behavior could account for the unchanged score. This emphasizes the need for improvements to the housing environment of dairy cows to encompass more than just the floor surface and, in particular, to include improvements to the stall design (Bell and Huxley, 2009).

The enhanced comfort of the rubber floor, compared with concrete, increased the number of observations of animals resting in the alley (Platz et al., 2008). Contrary to expectations, this did not increase the dirtiness score of the cows (Figure 4). These findings suggest that the increased number of observations of cows lying in the alley is attributable to only a small number of cows that showed this behavior on the slatted rubber mats, thereby not being able to increase the score. Moreover, 2 important factors determining the dirtiness of the animal, the maintenance of the cubicles and the dirtiness of the floor (Figure 5) remained unchanged. Furthermore, the scoring system used approximates the real dirtiness and may lack sensitivity in scoring larger regions, and this should be taken into account. Regardless, dirtiness is very important, as it is known that the scores for the udder and the lower hind limbs are associated with SCC in the milk (Schreiner and Ruegg, 2003; Reneau et al., 2005). The scores for these regions (udder, lower leg) were unchanged throughout the study (data not shown).

The higher activity levels of the cows on soft flooring (Platz et al., 2008) did not result in lower dirtiness scores for the rubber flooring (Figure 5). This contrasts with the findings of Benz (2002), who underlined the improved self-cleaning functions of soft flooring due to the higher activity of the cows. A possible reason for the lack of improved floor dirtiness may have been the floor cleaning practice applied [i.e., just scraping the manure manually from areas with low cow traffic (at the rear curb of the stalls) to the more frequented areas of the alleys (in the middle section of the floor elements)].

In contrast to calves, in which climatic conditions and ammonia concentrations indoors play an important role in the clinical outcome of multi-factorial infectious diseases (Lundborg et al., 2005), these factors are of much less concern in adult cattle. This is because only low concentrations of ammonia are found in open barns. Neither the dirtiness of the floor (Figure 4) nor the temperature inside the barn (Figure 6) changed when the rubber flooring was installed so, it was not surprising

that the ammonia gas concentrations were unaffected (Figure 6). It was not possible to evaluate the situation during the warmer months in the present study. It is known that ammonia emission is correlated with the temperature of the air inside the barn (Kavolelis, 2006), which most likely depends on differences in bacterial urease activity (Braam et al., 1997).

It must be stressed that a single-system design was used to obtain the data. Such a design is used to evaluate the effect of an intervention in applied research (Evans et al., 2006). In this type of study, subjects serve as their own control, thereby providing a detailed insight into the process and the effect of the intervention (i.e., covering the concrete slats with slatted rubber mats). By doing this, a very sensitive method is used to detect changes due to the intervention. The results cannot be generalized to a larger population (Evans et al., 2006). Therefore, further investigations on changes in flooring are needed with the option of combining the results via meta-analysis to increase the power.

In conclusion, unlike the beneficial effects on cow behavior that were indicative of an improvement in well-being, the rubber flooring did not have a positive influence on hoof health. Risk factors for infection such as skin lesions and the dirtiness of the cows and the flooring were unchanged by the change to rubber flooring, although absolute humidity increased. Therefore, providing soft flooring in a dairy barn is a good initial step, but other elements of animal hygiene and housing design must be included in any attempts to improve housing conditions for dairy cows.

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