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Leg lesions and cleanliness of finishing bulls kept in housing systems with different lying area surfaces

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Abstract

The influence of the quality of different lying surfaces on lesions and swellings at the joints as well as on the cleanliness of finishing bulls throughout the fattening period was studied. On 17 farms (623 bulls), pens with fully slatted concrete floors (CONCRETE), with rubber coated slats (RUBBER), with cubicles (CUBICLES, provided with five different types of soft lying mat) and with a littered lying area (STRAW) were compared. Bulls kept on STRAW developed the smallest lesion scores at the joints. In CUBICLES, there was a huge variability in the lesion scores depending on the type of lying mat, ranging from values comparable to STRAW up to and greater than the values for CONCRETE. The highest lesion scores at the carpal joints were found on CONCRETE, with intermediate values on RUBBER and in CUBICLES. At the tarsal joints, lesion scores were similar on CONCRETE and RUBBER and in the same range or worse on most mats in the CUBICLES. Swelling scores were highest on CONCRETE and intermediate on RUBBER and in CUBICLES compared to STRAW. In general, there was a steady increase in the lesion scores of the leg joints throughout the fattening period on CONCRETE, RUBBER and STRAW, whereas on some of the mats in CUBICLES these scores were at a high level from early on in the fattening period. Animals in all the housing systems were clean over the whole fattening period. Littering the lying area in CUBICLES affected neither the lesion scores nor the swelling scores at the joints nor animal cleanliness. In conclusion, both rubber coated slats and cubicles provided with soft lying mats were favourable with regard to the levels of lesions and swellings of the leg joints of finishing bulls compared to concrete slats. However, these levels were even lower in pens with a straw bedded lying area.

Keywords: Finishing bulls; Housing system; Lying area; Leg lesions; Cleanliness

1. Introduction

Finishing bulls are usually housed under intensive conditions. In most European countries the conventional housing system is a group pen with fully slatted concrete floors but many bull welfare problems arise within this system. Graf (1979), Mayer et al. (2002) and Ruis-Heutinck et al. (2000) have all noted significant alterations in the lying behaviour of bulls kept on a concrete floor, such as a higher proportion of atypical lying down and standing up movements and fewer periods lying in comparison to bulls kept in pens with a bedded lying area. Consequently, these authors regard a hard lying surface as unsuitable for the lying behaviour of finishing bulls.

As an improvement over concrete slats and as an alternative to housing with a straw bedded lying area, bulls can be kept in pens with rubber coated slats (Ruis-Heutinck et al., 2000; Friedli et al., 2004) and in pens with cubicles provided with soft lying mats (Schulze Westerath et al., 2005). These authors found positive effects on the bulls' lying behaviour in these alternative systems with less atypical lying down and standing up movements on softer lying surfaces or fewer incomplete lying down movements exhibited.

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In addition, improved lying area quality could have beneficial effects on the occurrence and severity of injuries. Schrader et al. (2001) recorded more tail tip lesions in bulls kept on slatted floors compared to those having access to a straw-bedded lying area. Other authors found fewer lesions of the cartilage at the carpal joints of bulls or steers in housing systems with softer lying surfaces (Ruis-Heutinck et al., 2000; Smits et al., 1995).

To our knowledge, no investigation has been conducted on finishing bulls to examine the influence of the type of lying area on less severe lesions at the joints, such as hairless patches or wounds. In a series of studies on cows, more alterations of the integument at the leg joints, hairless patches, hock lesions or swellings were found on harder compared to softer surfaces such as concrete or rubber surfaces versus deep bedding with straw or sand in cubicle housing systems (Livesey et al., 2002; Vokey et al., 2001; Weary and Taszkun, 2000; Wechsler et al., 2000). Lesions of the integument may develop and deteriorate into more severe injuries, such as inflammation of the joint due to continuous pressure and friction on the lying surface (Müller, 2004) and these effects can be assumed to be greater with heavier animals. Injuries need to be taken seriously, as an animal's health status may become so impaired that the profitability of production declines due to insufficient weight gain or additional costs of veterinary care (Müller, 2004) in addition to being a serious impairment to well-being through pain, or chronic discomfort.

In cows, adding litter on top of the soft lying mats in cubicles was found to improve the health of the animals' leg joints (Kögler et al., 2004; Rodenburg et al., 1994). In the case of bulls, it could be that adding litter to mats in cubicles impairs urine run-off from the lying area and thus inhibits drying of the lying surface, but, to our knowledge, this has not yet been tested.

Wetness and soiling of the lying area, which translate into animal wetness and dirtiness, may cause new lesions or aggravate existing lesions of the integument of cattle due to chemical components of the excrement attacking the skin or underlying tissue (Hartmann et al., 1997; Müller, 2004). For purposes of meat hygiene at the abattoir, it is recommended or even required that cattle sent for slaughter are clean so as to avoid carcass contamination with faecal pathogens from the hide (Pennington, 1997). Therefore, attention has to be paid to the cleanliness of the lying area. Different lying surfaces may soil in different ways depending on dung accumulation and removal and the texture of the lying surface.

The aim of the present study was to assess the influence of the quality of the lying surface on the occurrence, severity and development of injuries at the joints and on the cleanliness of finishing bulls. We investigated these parameters on farms where the bulls were kept in (a) pens with fully slatted concrete floors, (b) pens with rubber coated slatted floors, (c) cubicle housing systems with different types of soft lying mats which were either bare or lightly littered or (d) pens with a bedded lying area (either deep bedding or straw on a sloping floor).

We expected an increase in the number and severity of lesions and swellings at the leg joints with increasing duration that the bulls were kept on the respective surface and with increasing hardness of the lying surface, i.e. from the bedded lying area to rubber coated slats or soft lying mats in cubicles and to concrete slats. Litter added on top of the soft lying mats was expected to reduce the lesions at the leg joints.

2. Materials and methods

2.1. Animals and housing conditions

The investigation was carried out on a total of 623 finishing bulls and oxen of different breeds (Angus, Brown Swiss, Holstein, Limousin, Simmental and various crossbreeds) in 59 batches. Up to the age of four months, all the animals were raised in groups in pens with a straw bedded lying area, according to the requirements of Swiss animal welfare legislation. Thereafter and until slaughter at a weight of about 550 kg, they were housed in one of the four housing systems investigated on a total of 17 farms. Table 1 gives an overview of the numbers of farms, batches and animals examined with each type of lying surface.

The pens with concrete slats (CONCRETE) were located in insulated buildings. The space per animal was adapted to the weight of the animals during the fattening period in compliance with or slightly more generous than the minimal requirements of Swiss animal welfare legislation. Space allowance varied, e.g. between 2.5 and 2.9 m^2 per bull at a weight >400 kg. Bulls were housed in groups of 7–12 animals.

The fully slatted pens with rubber coated slats (Lospa, Kraiburg; RUBBER) were located in the same type of buildings as already described for the concrete slatted floors. Groups sizes were between 8 and 15 animals.

The pens with cubicles (CUBICLES) consisted of a lying area divided into cubicles by partitions and an additional solid or slatted concrete walking and feeding area. In all the pens but one, part of the walking area was unroofed. In half of the pens, the lying area was roofed and sheltered with walls on three sides only. In the other pens, the cubicles were located indoors. The animal-to-cubicle ratio was never greater than 1:1. Sometimes there were slightly more cubicles than bulls when animals were taken from the group. Cubicle dimensions were adjusted to the size of the animals by moving batches of animals to pens with larger cubicles according to different weight classes (cubicles between 0.70×1.50 m at approximately 200 kg and 1.10×2.40 m at approximately 500 kg body weight). The lying area in the cubicles was furnished with five different types of soft lying mat: A (KSL, Kraiburg: rubber mat with nubs on the underside), B (Green Mat, Boutech: foamed ethylene vinyl acetate [EVA] mat), C (Cow Comfort, Boutech: foamed EVA mat), D (KEW, Kraiburg: layer of foam

Table 1
Number of farms, batches, animals and animals per batch investigated on the different lying surfaces

Lying surface		Number of			
		Farms	Batches	Animals	Animals per investigated batch
CONCRETE		5	10	97	7–12
RUBBER		5	10	105	8–15
CUBICLES	mat A	3	7	68	5–20
	mat B	3	7	78	5–23
	mat C	1	4	40	10
	mat D	2	4	40	1–28
	mat E	2	8	69	1–19
STRAW		5	9	126	8–25

with rubber mat cover) and E (Pasture, mattress, tubes filled with granulate, covered with a layer of waterproof textile). All cubicles in a given pen were equipped with a single type of lying mat. The mat extended to the rear edge of the lying area and there was no bedding retainer. Housing groups consisted of 4–28 animals.

In the pens with straw bedding in the lying area (STRAW), the lying area consisted of either deep bedding or a sloped floor with straw bedding. The space per animal was adapted to the weight of the animals during the fattening period. For example, for the heaviest animals (>400 kg) the space per bull in the lying area was between 2.4 and 3.7 m^2. The lying area was either roofed and sheltered on three sides (three farms) or located in buildings (two farms). In addition to the littered lying area, all the pens had an area of solid or slatted concrete floor as a walking and/or feeding area. On three of the five farms, parts of these areas were unroofed. Group sizes were between 9 and 25 animals.

In the cubicle housing system, the effect of litter added to the lying mats was investigated with a total of 97 bulls in 12 batches on two farms (group sizes 4–10). On each farm, the cubicles were provided with one of two types of lying mat (soft rubber mat A and foamed EVA mat B or C) per pen. The lying area of all the cubicles in a given pen was either lightly littered or bare for the whole fattening period.

These studies were conducted in line with procedures prescribed by Swiss animal welfare legislation and approved to be in accordance with the relevant legislation (concerning experimental design and housing conditions).

2.2. Data collection

All of the experimental animals were individually weighed at the beginning of housing on the different lying surfaces and then at regular intervals of about eight weeks by means of a mobile scale. While the bulls were fixed in the scale, the number, type and size of lesions at the carpal joints and the tarsal joints (hock; lateral part of the tarsal joint and the medial and dorsal parts of the tuber calcis) were recorded. We registered the occurrence of hairless patches, scabs and wounds and their extent (<2 cm, 2–5 cm and >5 cm). Based on the results of a given inspection, a lesion score was calculated separately for the carpal and tarsal joints of each individual bull as the sum of the single scores of all observed alterations in the integument (Table 2). The absence of alterations was scored as zero.

In addition, swellings of varying severity (light, medium, severe) at the carpal and tarsal joints were recorded and a swelling score was calculated per animal by adding up individual scores of 1, 2 and 3 for light, medium and severe swellings at each of the joints, respectively.

We also recorded the dirtiness of eight body parts of the bulls: area around the tail, lower leg (shank of fore and hind leg), thigh, shoulder, belly, sternum and carpal joints by means of a score ranging from 0 (clean) to 2 (totally soiled) in increments of 0.5 according to the scoring system used by Faye and Barnouin (1985). For areas present on both sides of the body, only the score for the dirtier side was registered. For the purposes of analysis, an average score over all body parts was calculated for each individual bull for a given inspection.

2.3. Statistical analyses

To evaluate the data, (generalised) mixed-effects models (method 'lme'; Pinheiro and Bates, 2000 or method 'glmmPQL', Venables and Ripley, 2002) were used in R 1.9.1 (R Development Core Team, 2004).

In the analysis of the effects of the different types of lying surface, the models were of the form:

$$y_{ijklmn} = \mu + b_i + b_{ij} + b_{ijk} + \alpha_l + \beta_m + \gamma_n + \alpha_l : \beta_m + \beta_m : \gamma_n + \alpha_l : \gamma_n + \varepsilon_{ijklmn}$$

with the intercept μ, the fixed effects α_l, types of lying area (factor with eight levels: CONCRETE, RUBBER, CUBICLES with five different mat types, STRAW), β_m, duration that animals had been kept on the different types of lying area ('time on lying area': number of days, continuous), γ_n, weight of the animals (kg, continuous) and $\alpha_l : \beta_m + \beta_m : \gamma_n + \alpha_l : \gamma_n$, all possible two-way interactions of the

Table 2
Single scores for different types and sizes of lesions which were summed to calculate the lesion scores for the carpal and tarsal joints of a given animal

Lesion	Extent (cm)	Single score
Hairless patches	<2	1
	2–5	2
	>5	3
Scabs	<2	2
	2–5	4
	>5	6
Wounds	<2	2
	2–5	4
	>5	6

fixed effects and the nested random effects b_i, farm, b_{ij}, batch and b_{ijk}, animal. We included weight of the animals as an explanatory variable, because it was not directly correlated with the time the bulls had spent on the lying surface, due to differences in weight gain and different weights at the beginning of housing on the various lying surfaces.

To compare the effects of adding litter to the lying mats, the fixed effect α_l was type of soft lying mat (factor with two levels: rubber mat A, foamed ethylene vinyl acetate mat B or C). Presence of litter (yes/no) was included as an additional fixed effect δ_o and $\alpha_l:\beta_m + \beta_m:\gamma_n + \alpha_l:\gamma_n + \alpha_l:\delta_o + \beta_m:\delta_o + \gamma_n{:}\delta_o$ were all possible interactions of the fixed effects. This resulted in a model of the form:

$$y_{ijklmno} = \mu + b_i + b_{ij} + b_{ijk} + \alpha_l + \beta_m + \gamma_n + \delta_o + \alpha_l:\beta_m + \beta_m:\gamma_n + \alpha_l:\gamma_n + \alpha_l:\delta_o + \beta_m:\delta_o + \gamma_n:\delta_o + \varepsilon_{ijklmno}.$$

Statistical assumptions in these models are that $\varepsilon \sim N(0,\sigma^2)$ iid, $b_i \sim N(0,\sigma_1^2)$ iid, $b_{ij} \sim N(0,\sigma_2^2)$ iid and $b_{\text{iid}} \sim N(0,\sigma_3^2)$ iid (iid = independently identically distributed). These assumptions, homoscedasticity and independence of the residuals from the explanatory variables were checked using graphical analysis of residuals. To satisfy these assumptions some responses were log (dirtiness scores) or square-root (lesion scores) transformed. For swelling scores, alternative distributions were used (Poisson distribution for general comparison of the lying surfaces and binomial distribution for comparing mats with and without additional litter).

In general, we were only interested in the main effects of the type of lying area and of the presence of litter on the lying mats. Thus, these effects and their interactions with time on lying area and body weight are presented in the results and are later discussed. For all response variables, these interactions reached significance. Changes with time or weight differed considerably between the types of lying area, however, and no general interpretation of the main effects of time on lying area and body weight was possible. Directions of differences were interpreted based on the figures in the results section and on figures showing model estimates (not shown).

3. Results

3.1. Lesions

The lesion scores at the carpal joints were low for the animals kept on STRAW, high when kept on CONCRETE and in CUBICLES with mat A and intermediate when kept on RUBBER and in CUBICLES with the other mats (B, C, D and E; $F_{7,35} = 24.465$; $P < 0.001$; Fig. 1a).

On CONCRETE, RUBBER, STRAW, and in CUBICLES with mat B, the lesion scores at the carpal joints increased progressively with time spent on a given lying surface. No such clear pattern was found on the other lying surfaces (type of lying area-time on lying area-interaction: $F_{7,1743} = 49.878$, $P < 0.001$; Fig. 1a). At all times, heavier animals had higher lesion scores in CUBICLES with mat C and on CONCRETE than lighter animals, whereas weight did not seem to influence the lesion scores on the other lying surfaces (type of lying area-weight-interaction: $F_{7,1743} = 3.773$, $P < 0.001$).

At the tarsal joints, bulls kept on STRAW and in CUBICLES with mat E had low lesion scores and animals in CUBICLES with mats A and B had the highest lesion scores; the lying surfaces CONCRETE, RUBBER and CUBICLES with mats C and D showed an intermediate amount of lesions ($F_{7,35} = 11.36$; $P < 0.001$; Fig. 1b).

We found a steadily increasing lesion score for the tarsal joints with time spent on a given lying surface on CONCRETE, RUBBER and CUBICLES with mats A, B and E and STRAW, but no such changes on the other lying surfaces (mats C and D; type of lying area-time on lying area-interaction: $F_{7,1743} = 52.468$, $P < 0.001$; Fig. 1b). The heavier animals had lower lesion scores when kept on CUBICLES with mats C and D and on the other types of lying area there was only a slight weight effect on the lesion score (effect of type of lying area–weight-interaction: $F_{7,1743} = 3.236$, $P = 0.002$).

3.2. Swellings

There was a difference in the swelling scores at the leg joints between the lying surfaces investigated ($F_{7,35} = 3.093$; $P = 0.012$; Fig. 2). Swelling scores were lowest on STRAW, highest with bulls on CONCRETE and intermediate on RUBBER. The scores in CUBICLES differed depending on the type of soft lying mat, varying between levels almost as low as STRAW (mats B, C and E) and as high as RUBBER (mats A and D).

The swelling score increased with time on the lying surface in bulls on CONCRETE, RUBBER and STRAW, whereas on the mats in CUBICLES no such pattern was found (type of lying area-time on lying area-interaction: $F_{7,1743} = 16.574$, $P < 0.001$; Fig. 2). With increasing weight, the bulls had higher swelling scores on CONCRETE and in CUBICLES with mats C and E. The lighter animals had higher swelling scores in CUBICLES with mat B. No influence of the animals' weight on the swelling score was detected for the other lying surfaces (type of lying area–weight-interaction: $F_{7,1743} = 6.629$, $P < 0.001$).

3.3. Cleanliness of the animals

The dirtiness scores of all eight body parts considered were fairly low. A qualitative inspection of the data showed that the pattern of soiling was slightly different in animals kept in cubicles compared to the other housing systems. Bulls in cubicles showed somewhat greater soiling on the hind part of their bodies, while soiling on the front part of the body was more common in animals on unstructured

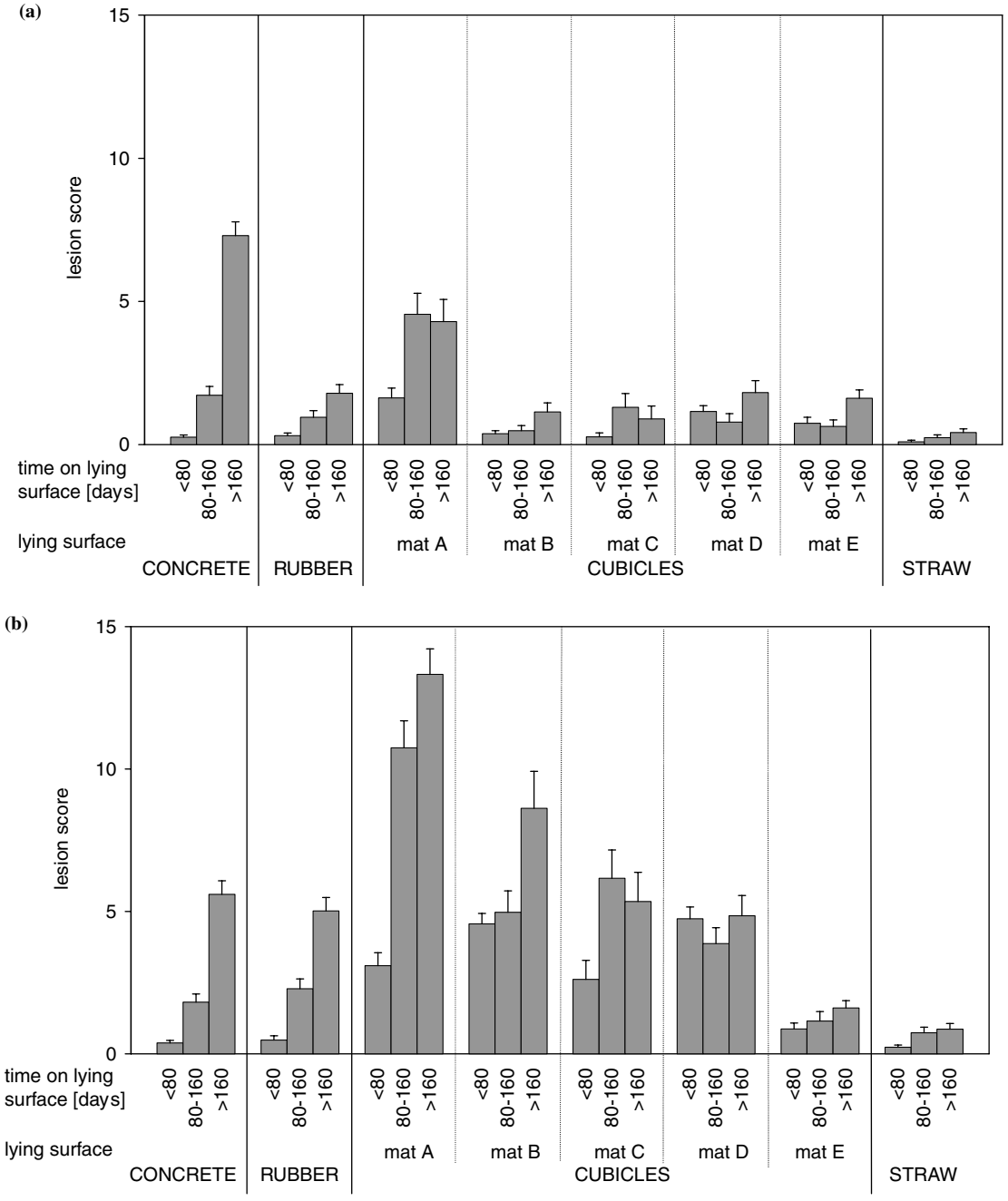

Fig. 1. Lesion scores at the carpal joint (a) and at the tarsal joint (b) (means and standard errors) of finishing bulls kept in housing systems with different types of lying area in relation to the time they had been in each system.

lying areas. There was no apparent difference between the housing systems in terms of soiling on the belly region.

The bulls' mean dirtiness score was slightly lower in animals kept in CUBICLES with four of the lying mats (except mat E) than in bulls kept in pens with the other lying surfaces, but this difference did not reach significance ($F_{7,35} = 2.101$; $P = 0.065$; Fig. 3). With all lying surfaces, the absolute dirtiness scores were low, indicating that the animals were generally clean.

The change in the dirtiness scores with time spent on a given lying surface was different for the different types of lying area (type of lying area-time on lying area-interaction: $F_{7,1729} = 8.175$, $P < 0.001$), but these changes were slight (Fig. 3). The heavier animals had higher total dirtiness scores on RUBBER, STRAW and in CUBICLES with mats B and C and there was no obvious difference for the other types of lying mat (effect of type of lying area–weight-interaction: $F_{7,1729} = 2.019$, $P = 0.0495$).

3.4. Litter on the lying area in cubicles

The litter regime (with or without litter on the lying mats in the cubicles) had no significant effects on the injury scores for the carpal ($F_{1,7} = 0.04$; $P = 0.85$) and tarsal

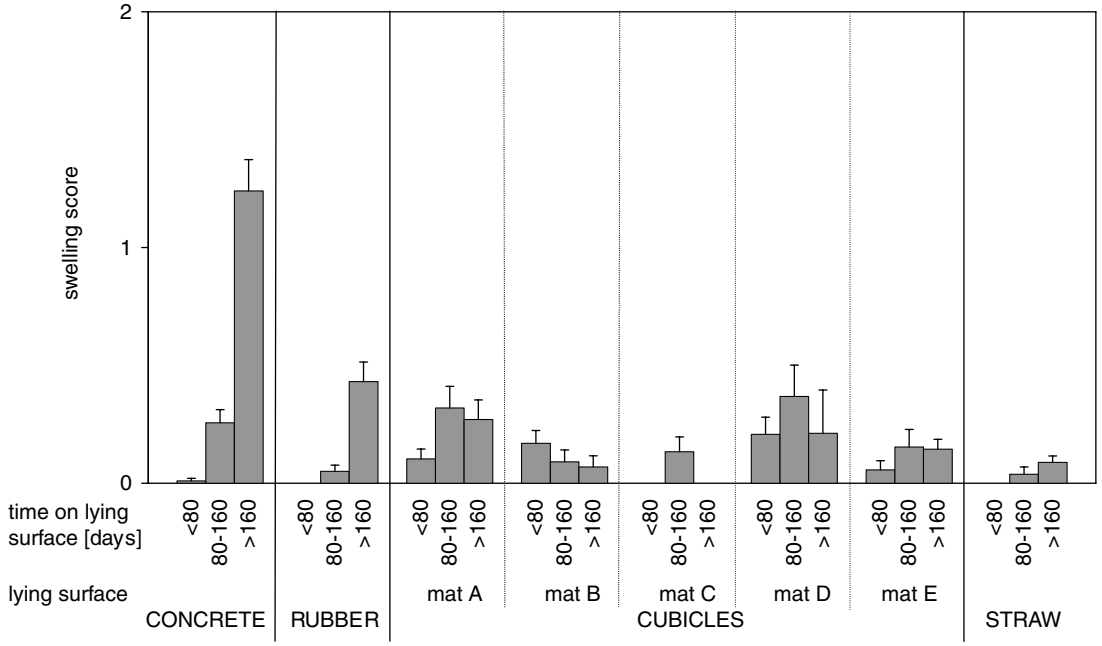

Fig. 2. Swelling scores at the carpal and tarsal joints (means and standard errors) of finishing bulls kept in housing systems with different types of lying area in relation to the time they had been in each system.

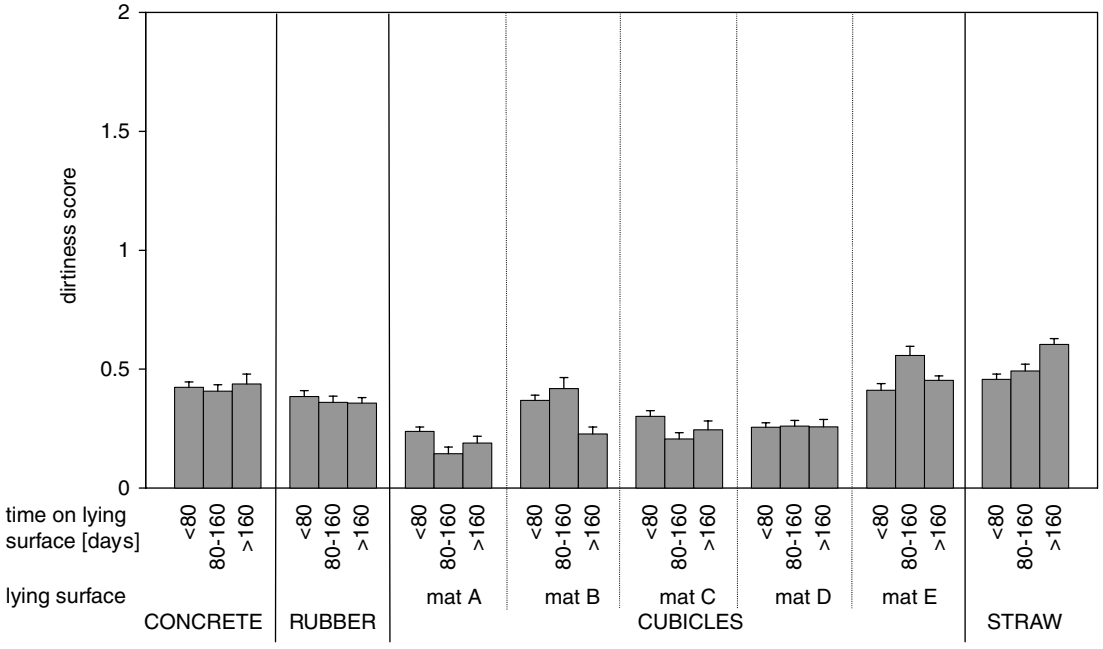

Fig. 3. Average dirtiness scores (means and standard errors) of finishing bulls kept in housing systems with different types of lying area in relation to the time they had been in each system.

($F_{1,7} = 1.296$; $P = 0.292$) joints. There was no influence of the litter regime on the swelling score ($F_{1,7} = 1.136$; $P = 0.322$), either. However, with litter added to the lying area, the probability of occurrence of swellings increased less with increasing time spent on the mats compared to the lying mats without litter (litter-time on lying area-interaction: $F_{1,224} = 5.4$; $P = 0.021$). There was no difference in the cleanliness of bulls kept in cubicles with or without litter on the soft lying mats ($F_{1,7} = 1.814$; $P = 0.22$).

Absolute values of lesion, swelling and dirtiness scores in the data used for evaluating the effect of adding litter on the lying mat were found to be reflected in the complete data set comparing the different types of lying surface in terms of the influence on the different parameters. There-

fore, levels of the absolute values for mats A, B and C can be seen in the corresponding figures (Figs. 1–3).

4. Discussion

4.1. Lesions and swellings

In general, the bulls in pens with a bedded lying area had the lowest lesion and swelling scores. This confirms the positive effect of a bedded lying area (either sand or straw) compared to harder lying areas (concrete, mats and mattresses) on leg health, as has already been shown in heifers (Livesey et al., 2002) and cows (Vokey et al., 2001; Weary and Taszkun, 2000; Wechsler et al., 2000).

As expected, the highest lesion scores at the carpal joints and the highest swelling scores were found in pens with slatted concrete floors, reflecting the results of studies on dairy cows in tie stalls (e.g. Haley et al., 1999; Nilsson, 1988). Contrary to our expectations, the lesion scores at the hocks were not highest on the concrete slats, but lower than the scores on some of the lying mats in cubicles and similar to the scores on rubber coated slats.

Considering fully slatted floors only, there was no obvious influence of the rubber coating on the lesion scores at the tarsal joints, whereas the lesion scores at the carpal joints and the occurrence of swellings were lower on coated slats. This positive influence is supported by studies by Ruis-Heutinck et al. (2000) and Smits et al. (1995) on bulls housed in slatted pens with either bare concrete or rubber coatings: they found fewer lesions of the articular cartilage of the carpal joints on the softer lying surfaces. They inferred that the rubber cover improved the housing conditions with regard to leg lesions in fully slatted pens.

Carpal and tarsal lesion scores as well as swelling scores showed considerable variability over the types of soft lying mat investigated, indicating a difference in the quality of the lying area. The sequence in which the mats are shown in the figures corresponds approximately to the increasing softness of the mats (A: rubber, B/C: foamed, D: rubber coated foam and E: mattress). This variation in softness could explain the pattern of the tarsal lesion scores (decrease from A to E). At the carpal joints, the pressure is only exerted for a short time (while lying down and standing up) and only mat A seemed to be hard enough to increase the lesion scores. The swelling scores were highest for mats A and D which were both made of rubber, and these two mats also showed swelling scores similar to those on rubber coated slats. Nevertheless, at the end of the finishing period, the swelling score on the rubber coated slats was higher than on the rubber mats (A, D), thus confirming the assumption that harder floors cause more swellings due to a poorer blood supply (Müller, 2004) and greater external trauma. With cows, some studies have also found that there were fewer leg injuries if the animals were kept in cubicle systems with mattresses compared to harder mats (Livesey et al., 2002; Rodenburg et al., 1994). However, Chaplin et al. (2000) did not detect any such differences related to the softness of the mat with cows.

Though lesion scores varied over a broad range on the different lying mats, investigations of the lying behaviour of bulls in pens with cubicles provided with mats A, B, D and a different type of mattress showed no difference in the lying duration per day and the frequency of lying bouts (Schulze Westerath et al., 2005). In addition, a choice test with mats A and B as lying surfaces in cubicles showed the bulls had no preference for either of the mats (Schulze Westerath et al., 2005). Thus, the differences in lesion scores in this study were not reflected in the bulls' behaviour observed in previous studies. Higher lesion and swelling scores cannot therefore be explained by longer lying durations or more frequent lying-down and standing-up movements, and bulls do not seem to exhibit preferences between types of lying mats that differ in their effect on alterations of the leg joints.

Most lying mats had a similar or worse effect on the lesion scores than rubber coated slats, especially at the tarsal joints. Unexpectedly, the scores on the mats were already at a relatively high level in the early phase of housing. In addition, a steady increase in the scores at the hocks was observed on rubber coated slats, whereas this pattern was different with most of the mats. These findings may be explained by differences in the softness or the surface structure of mats and rubber coated slats. Moreover, the bulls' joints touch the ground over a larger contact area on solid mats than on a perforated slatted floor, with the possibility of influencing the joints to a greater extent. The reduced pressure due to the larger contact area does not seem to compensate for the larger size of the contact area. This may indicate that surface friction is more relevant to the development of superficial lesions at the hocks than lack of softness. Finally, differences in lying-down and standing-up movements on mats compared to rubber slats due to the restricted space and/or the sloped lying area in cubicles may result in differences in pressure and friction at the hocks.

The findings of higher lesion scores at the carpal than at the tarsal joints on concrete slats and the inverted pattern on all mats in cubicles (except the mattress, mat E) and on rubber coated slats suggest that alterations at the carpal joint are mainly influenced by the pressure on the ground and therefore by the hardness of the lying area. In line with this explanation, the lesion scores at the carpal joints on concrete slats were markedly higher in heavier bulls.

An explanation for the high lesion scores at the tarsal joints observed in bulls kept in cubicles could be that the cubicles were too short, causing the animals to lie on the rear kerb of the cubicles with the joints of their hind legs. However, cubicles of the same length were found to be suitable for bulls in another study (Gygax et al., 2005). These authors did not find any indication that bulls were lying on the rear kerb. In the present investigation, no bulls were seen lying on the kerb (qualitative observations). Bulls were seen to lie on the kerb in a previous study in which the bulls

were in cubicles (Schulze Westerath et al., 2006) but only if the slope of the lying area >8%, which was not the case for the test farms in the current study, which had slopes of <5%. The difference in pattern between the lesion scores at the carpal and tarsal joints was not observed in the swelling scores. We could not formally test the swelling scores for the front and hind legs separately, however, as the relatively low occurrence of swellings led to numerical problems in the modelling process. A qualitative inspection of the data showed that the mean swelling scores at the tarsal joints in bulls kept in cubicles were similar to those in bulls on concrete slats, whereas the swelling scores at the carpal joints were considerably lower in bulls kept in cubicles than in those kept on concrete slats.

4.2. Cleanliness

The bulls in the housing systems investigated were very clean overall and there was no indication of impaired animal welfare due to dirtiness. No differences in the cleanliness of the animals could be detected between the different lying surfaces. Previous studies have reported contradictory results regarding animal cleanliness in different housing systems. Several authors found that bulls were dirtier in slatted pens compared to animals kept with a littered lying area (Hartmann et al., 1997; O'Hagan and Steen, 2000; Lowe et al., 2001; Konrad, 1988), but Hickey et al. (2002) found that steers in slatted pens were cleaner than those in out-wintering pads and Scott and Kelly (1989) found no differences in the cleanliness of growing cattle kept on concrete, bedded or slatted floors or in cubicles. Taking only cubicles with lying mats into account, Chaplin et al. (2000) found slightly dirtier cows on a mattress than on a mat, whereas Rodenburg et al. (1994) and Veissier et al. (2004) reported that dairy cows kept on mattresses were cleaner than those kept on mats.

4.3. Litter on soft lying mats in cubicles

Littering soft lying mats in cubicles did not affect the animals' lesion scores. Only the probability of the occurrence of swellings increased less with increasing time spent on the mats when litter was added to the lying area compared to when there was no litter. Findings that additional litter reduces the injuries at the leg joints in dairy cows in cubicles with lying mats (Kögler et al., 2004; Rodenburg et al., 1994) as well as in tie stalls (Wiederkehr et al., 1999) could therefore not be confirmed in our study with bulls. Differences between dairy cows and bulls could arise because cows are kept much longer in the housing systems than bulls. The concern that bulls would be dirtier in cubicles with litter added on top of the lying mats due to impaired urine drying was not confirmed. The dirtiness scores were not influenced by littering the lying mats and the bulls kept in pens with cubicles were very clean.

5. Conclusions

Lesions and swellings at the leg joints were fewest and slightest in finishing bulls kept in pens with a straw bedded lying area, worst on concrete slats and intermediate on rubber coated slats. Among the slatted floors, rubber coating reduced lesion and swelling scores. Mats in pens with cubicles varied widely in their effect on the bulls' lesion scores and the scores on most of the mats were comparable to those found on rubber coated slats. Littering the mats in cubicles did not have a beneficial effect on the lesion scores. All lying surfaces compared here can be considered suitable with regard to animal cleanliness.

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