Comparison of the rate of claw horn growth and wear and sole thickness in Dairy Cattle housed in a free stall barn with concrete and rubber flooring

Sarel Van Amstel, Charles Young, Clare Scully, Barton Rohrbach

Background. Thin soles and resulting lameness in cows are often due to abrasive walking surfaces that cause increased wear. The aim of this project was to compare horn growth and wear and sole thickness in cows kept on rubber mats versus concrete in a free-stall barn. Methods. To examine horn growth and wear and sole thickness, we examined two groups (Group 1 kept on concrete [control] and Group 2 on rubber mats) of 12 cows each at 2-week intervals over a 12-week period. The 12 cows in each group were selected to achieve equal parity in each group, as follows: four cows, parity 1; four cows, parity 2; two cows, parity 3; and two cows, parity 4. The four cows from the parity 1 group had the most days in milk in the herd irrespective of milk production. The remaining eight cows had the fewest days in milk (most recently calved) irrespective of milk production. Results. Cows in the control group had a significant increase in claw horn growth over the study period, compared to the control group. Most of this difference in horn growth occurred during the first 2 weeks of the study. There was no significant difference in claw horn wear and sole thickness at 2 weeks or at the end of the study. There was, however, a non-significant difference in wear between cows in the 2 groups at the end of the study, with cows in the control group showing most wear. Cows in the experimental group exhibited significant increases in all parameters (claw length, wear, and growth; sole thickness) when measured at the beginning and end of the trial, whereas cows in the control group showed a significant increase in claw length and sole thickness.

Discussion. These findings suggest that there was a compensatory increase in horn production in response to accelerated claw horn wear in the control group. Statistical significance in wear might have been attained between groups at the end of the study if the study had continued over a longer period.
Comparison of the Rate of Claw Horn Growth and Wear and Sole Thickness in Dairy Cattle Housed in a Free Stall Barn with Concrete and Rubber Flooring

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ABSTRACT

Background. Thin soles and resulting lameness in cows are often due to abrasive walking surfaces that cause increased wear. The aim of this project was to compare horn growth and wear and sole thickness in cows kept on rubber mats versus concrete in a free-stall barn.

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Keywords Dairy cows, Housing, Claw, Sole
INTRODUCTION

Lameness has a multi-factorial etiology in dairy cattle. Some of the factors affecting claw health and locomotion score in dairy cattle include season, housing type, stall and walking surface, claw horn quality and hardness, claw trimming method, use of a trimming chute and footbaths, and feeding silage (Barker et al., 2007; Sanders, Shearer & de Vries, 2009). Walking on concrete surfaces, in particular, has been identified as a cause of lameness in dairy cattle because it results in thin soles (Van Amstel et al., 2006). One method used to prevent the adverse effects of concrete on sole horn is the placement of rubber matting on walkways in free-stall and tie-stall dairies (Hultgren and Bergsten, 2001; Vanegas et al., 2006; Kremer et al., 2007; Telezhenko, Lidfors & Bergsten, 2007; Ouweltjes et al., 2009). Several studies have investigated the effects of concrete versus rubber on claw horn growth and claw lesions. One study found an increase in net horn growth in cows kept on rubber (Kremer et al., 2007). In that study, cows on rubber flooring also showed an increase in overall activity, but at the same time, an increase in the incidence of sole ulcers was found. An increase in net horn growth was likewise found in another study comparing rubber versus concrete walking surfaces (Samel, 2005). Jungbluth, Benz & Wandel (2003), on the other hand, found no differences in claw horn growth when comparing cows kept on rubber versus concrete. Two additional studies found that cows kept on rubber showed decreased horn growth (Vokey et al., 2001; Vanegas et al., 2006). Based on the somewhat conflicting results of the afore-mentioned studies, the purpose of this study was to examine the effect of a rubber surface compared with concrete flooring on claw growth and wear and sole thickness among dairy cows.

MATERIALS AND METHODS

Experimental design
The use of the animals in this study was approved by the Institutional Animal Care and Use Committee of the College of Veterinary Medicine, university of Tennessee. Twenty-four mature dairy cows were ranked in order according to lactation number and calving date. Using a randomized block design, each group of two cows was randomly assigned in ranked order to either the experimental (rubber mat, group 1) or the control group (housed on concrete, group 2). Sample size was calculated based on the assumption that one of 10 cows on rubber mats will have claw growth exceeding wear and eight of 10 cows on concrete will have wear exceeding growth. Given that changes in growth relative to wear presents the true effect of concrete versus rubber mats in the population, we had a 90% probability of finding a statistically significant difference between the study groups with 10 cows per group at the level of p < 0.05. Four cows were added to each group in order to compensate for the possibility that cows may be culled or die for reasons unrelated to the experimental procedure during the 12-week (84-day) study period.

Animals

Two groups of 12 adult dairy cows each were housed at the University of Tennessee Dairy. Group 1 (control) consisted of four cows at parity 1, four cows at parity 2, two cows at parity 3, and two cows at parity 4. The four cows from parity 1 had the most number of days in milk in the herd irrespective of milk production. The remaining eight cows had the fewest number of days in milk (most recently calved) irrespective of milk production. Cows in group 2 (rubber mat) were selected on the same basis as group 1 cows.

Feeding and housing

Twice daily, lactating cows were fed ad libitum a total mixed ration balanced to meet the nutritional requirements for mature Holstein cows. Both groups consisted of 12 cows, and cows
in each group were housed in separate pens. Pens consisted of 24 sand-bedded free-stalls and 30 self-locking head gates. The pen for group 1 consisted of grooved concrete flooring. The group 2 pen consisted of rubber flooring mechanically anchored to grooved concrete. Rubber mats were 1.83 m (6 feet) wide behind the self-locking head gate feeding area and 1.22 m (4 feet) wide behind each row of free stalls and near an outside alley.

Movement of animals

All cows were milked twice daily in a double 8 milking parlor with a solid concrete surface. Cows in both groups entered the milking parlor via an alley 31.70 m (104 feet) long and 2.74 m (9 feet) wide. This drover’s alley entrance was equipped with a 1.22 m (4 feet)-wide rubber mat extending the length of the alley and placed centrally. Cows from both groups exited the parlor via a return lane 31.70 m (104 feet) long with no rubber mat. Cows in the rubber treatment group were always milked first and placed directly into the milking parlor to limit their time on concrete. Cows in the concrete control group were milked following the rubber treatment group. Both groups were returned to their respective pens immediately following milking to limit excessive standing on concrete. Each week for four consecutive milkings, cows walked through a 5% formaldehyde footbath, which followed a water prewash bath.

Data collection

At week 0, cows were restrained in a mobile, stand-up leg chute and their claws trimmed based on a modification of the Dutch trimming method (Toussaint Raven, 1989). Only back claws were trimmed since it has been shown that the sole horns of back feet wear more quickly than those of front feet and are thus more prone to increased wear with resulting lameness (Van Amstel, Shearer & Palin, 2004). Each claw on the back feet was grooved horizontally and vertically using a power file (Fig. 1). A 1-mm mark on the blade was used as a guide to ensure that the
depth of the groove did not extend through the full thickness of the hoof wall. The horizontal line
was made below the periople (skin/horn junction) of the coronary band (Fig. 1). The first vertical
groove was made from just below the coronary band across the horizontal line to the weight-
bearing surface, midway between toe and heel (caudal wall segment), and the second was made
in a similar manner midway between the first vertical line and the toe (cranial wall segment)
(Fig. 1).

At 2-week intervals over 84 days, observers blinded to treatment group evaluated cows as a
comingled group. After grooving, the following measurements, using digital calipers (accurate to
0.1 mm), were taken at 2-week intervals on days 1, 14, 28, 42, 56, 70, and 84: from the skin/horn
junction (coronary band) to the horizontal groove at the junction of each vertical groove (Fig. 1,
A1 and B1) and from the top horizontal groove along each vertical groove to the edge of the
bearing surface (Fig. 1, A2 and B2). Following evaluation, cows were returned to their respective
pens.

**Calculations**

The extent of growth and wear for each claw were calculated as follows:

Growth (cranial segment) = A1 (previous) – A2 (current)

Growth (caudal segment) = B1 (previous) – B2 (current)

Wear (cranial segment) = A1 + A2 (previous) + growth – A1 + A2 (current)

Wear (caudal segment) = B1 + B2 (previous) + growth – (B1 + B2 (current)

Sole thickness was determined using a 7.5-MHz probe at each examination, as previously
described (*Van Amstel, Shearer & Palin, 2004*).
Data were analyzed sequentially, and the experiment terminated after 84 days. Data are expressed as the adjusted least squares means ± 1 standard error of the mean (SEM). A mixed-model analysis of variance was used to evaluate the effect of group on length of claw, growth, and wear and sole thickness over the 12-week observation period. Cow, group, leg, location, week, and lactation number were included as class variables in the model. Treatment, week, lactation number days in milk, weight, and the interaction between group and week were included as independent variables in the model. Week was treated as a repeated measure with subject equal to location within leg, cow, and group. The fit of the model to data was evaluated using the $-2$ log likelihood ratio, and the assumption that the residuals from the model conform to a normal distribution was assessed using the test statistic of Shapiro-Wilk. A p-value <0.05 was used to determine statistical significance in all tests. The proportion of cows exhibiting wear that exceeded growth among treatment groups were compared using the Fisher exact test.

**RESULTS**

Two cows, one from each group, were removed from the study due to unrelated health problems.

**Claw length**

The average claw length of hind claws at the start was 73.7 for group 2 (rubber) and 73.03 for group 1 (concrete), $p = 0.55$ (*Table 1, Fig. 2*). The average claw length at the end of the study was 75.91 and 75.62 for group 2 (rubber) and group 1 (concrete), respectively, $p = 1.000$ (*Table 2, Fig. 2*). The expected length (defined as length at the previous interval plus growth at the current interval) was also not significantly different among groups with an average length of 75.87 for group 2 (rubber) and 76.11 for group 1 (concrete), $p = 0.84$ (*Table 1, Fig. 3*).

**Claw growth**
The average growth of hind claws at each 2-week interval was significantly different. There was an average increase of 2.78 mm in horn growth for group 2 (rubber) compared with 3.26 mm for group 1 (concrete), $p = 0.02$ (Table 1, Fig. 4). When claw horn growth was compared among groups at week 2 of the study, a statistically significant difference was found in group 2 (rubber) 2.25 mm and group 1 (concrete) 4.35 mm growth, $p = 0.001$ (Table 2, Fig. 4). However, when measurements for growth during the last 2-week interval were compared, there was no difference in growth between the 2 groups with group 2 (rubber) at 3.86 mm and group 1 (concrete) at 4.18 mm, $p = 0.99$ (Table 2, Fig. 4).

Claw horn wear

There was no significant difference in average wear at each 2-week interval (defined as claw length at the previous interval plus growth minus claw length at the current interval) with an average wear of 2.25 mm among cows on rubber mats compared with cows on concrete at 2.42 mm, $p = <0.20$ (Table 1, Fig. 5).

Sole thickness

The average difference in sole thickness over the observation period was non-significant. Average sole thickness of cows in group 2 (rubber) was 9.78 mm, and 9.59 mm among cows in group 1 (concrete), $p = 0.59$ (Table 1, Fig. 6).

Comparisons within groups

When results of measurements over the 12-week study period within groups were compared cows in group 2 (rubber) showed significant differences for claw length, claw horn wear, growth and sole thickness over time, whereas cows in group 1 (concrete) showed significant differences for claw length and sole thickness only (Table 3).
DISCUSSION

This study found that cows on concrete had significantly more average claw horn growth (measured at 2-week intervals), compared to those on concrete over the course of 12 weeks. The biggest difference in growth between the groups occurred during the first 2 weeks of the experiment. Accelerated horn growth is often associated with increased rates of wear (van Amstel, Shearer & Palin, 2004). There was a small but non-significant increase in average wear in the cows kept on concrete compared to those kept on rubber both at 2 weeks and at the end of the study, which represents the average wear measured at each of the 2-week intervals.

Accelerated horn growth may occur under circumstances where there is increased mechanical removal of sole horn, such as with concrete walking surfaces or foot trimming (Vermunt & Greenough, 1995). The accelerated horn growth might explain why the difference in wear between the groups was non-significant. A possible explanation for accelerated or compensatory growth associated with accelerated claw horn wear is the presence of mechanoreceptors in the epidermis, which can result in accelerated horn growth through the release of epidermal growth factor (Buda & Mülling, 2000). Increased sole wear may increase pressure caused by weight bearing. This, as well as pressure from the concrete surface, may have contributed to the accelerated horn growth seen in this study. Various other factors apart from wear, such as age, breed, season, nutrition, environment and laminitis, have been reported to influence growth rates of claw horn (Vermunt & Greenough, 1995). However, based on the selection, nutrition, and environment, except for the walking surface of cows in the study, it seems unlikely that any of those factors could have played a role in the observed difference in growth rate between the experimental and control groups.
Increased rates of wear have been associated with concrete walking surfaces, poor cow comfort, commingling of animals, poor horn quality, poor stockmanship, and claw horn moisture exposure. In the current study, cow comfort (lying down time), stockmanship, claw horn quality, and exposure of horn to external moisture were the same between both groups. It therefore seems likely that the small difference in wear could be related to the walking surface in both groups.

Sole thickness and toe length can also correlate with the degree of wear (van Amstel, Shearer & Palin, 2004). Similar to wear, there was only a slight difference in sole thickness between the two groups, with the cows on concrete being slightly more thin-soled. This could also indicate that there is compensatory sole horn growth, which corresponds to the findings in other studies (Vokey et al., 2001; Vanegas et al., 2006).

A previous study has shown that cows with thin soles also had a short toe length when compared to cows with normal sole thickness of 5 to 7 mm based on ultrasound measurements (van Amstel, Shearer & Palin, 2004). This result also goes along with previous research in which a correlation between toe length and sole thickness was found (Toussaint Raven, 1989). However, in this study there was no difference in toe length between cows on concrete and those on rubber at the end of the 12-week period.

When claw measurements of cows within the same groups were compared, several statistically significant differences were found between results at the start (0–2 weeks) and end (10–12 weeks) of the experiment. For cows on rubber, all measurements were statistically different between those taken at the start and those at the end of the experiment. For cows in the concrete group, only length and sole thickness were significantly different. This appears to demonstrate fluctuations in claw horn over time and thus the necessity to use multiple measurements at given time intervals (Table 2). Both groups showed similar increases in toe...
length and sole thickness, emphasizing the fact that cows on concrete may also have to be trimmed periodically. Overgrowth at the toe and an increase in sole thickness can lead to changes in weight bearing, within the claw predisposing to sole ulceration (Toussaint Raven, 1989). The results of this study suggest that claw horn wear of cows on concrete was slightly faster than the rate of compensatory growth (faster growth but slightly thinner sole). Distance of travel to the milking parlor, abrasiveness and moisture of concrete flooring, number of times a day milking, and standing time are all factors that can determine the rate of claw horn wear (Shearer & Van Amstel, 2007). In this study, cows were milked twice daily, had only a short distance to walk on concrete to the milking parlor, and had good stall occupancy due to the stall size and sand bedding.

CONCLUSIONS

Results of the study indicate a possible protective effect of a rubber walking surface (versus concrete) against claw horn wear. Cows on concrete showed accelerated growth that did not fully compensate based on a tendency for increased wear and slightly thinner soles. Had the study continued longer or the walking distance to the milking parlor been greater, horn wear for cows on concrete could have been greater as compared to those on rubber.

Competing Interests

The authors declare that there are no competing interests.

REFERENCES


Figure legends

Figure 1  Horn grooves for measuring growth versus wear in dairy cattle.
Figure 2  Claw length measured at 2-week intervals in dairy cattle housed on concrete versus rubber mats.
Figure 3  Expected claw length at 2-week intervals in dairy cattle housed on concrete versus rubber mats.
Figure 4  Claw horn growth measured at 2-week intervals in dairy cattle housed on concrete versus rubber mats.
Figure 5  Claw horn wear measured at 2-week intervals in dairy cattle housed on concrete versus rubber mats.
Figure 6  Sole thickness measured at 2-week intervals in dairy cattle housed on concrete versus rubber mats.
Table 1. Average of claw measurements* among a group of cows (n=12) kept on concrete versus a group (n=12) maintained on rubber mats taken at two-week intervals over a twelve week period.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Concrete</th>
<th>Rubber Mat</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed length of claw++</td>
<td>73.03 ± 0.77</td>
<td>73.70 ± 0.77</td>
<td>0.55</td>
</tr>
<tr>
<td>Growth^,*</td>
<td>3.26 ± 0.14</td>
<td>2.78 ± 0.14</td>
<td>0.02</td>
</tr>
<tr>
<td>Expected length^,**</td>
<td>75.87 ± 0.80*</td>
<td>76.11 ± 0.80</td>
<td>0.84</td>
</tr>
<tr>
<td>Wear^</td>
<td>2.42 ± 0.09**</td>
<td>2.25 ± 0.09</td>
<td>0.20</td>
</tr>
<tr>
<td>Sole thickness++</td>
<td>9.59 ± 0.24</td>
<td>9.78 ± 0.24</td>
<td>0.59</td>
</tr>
</tbody>
</table>

+ measurements adjusted for week, lactation number, days in milk and cow weight.

++ measured at weeks 0-12

^ measured at weeks 2-12

* Growth at the end of the current interval + length of claw at measurement beginning of previous interval

** Expected growth – Observed growth at each interval.
Table 2. Comparison of measurements of claw length, growth, wear and sole thickness at the start and at 12 weeks among a group of cows (n=12) maintained on concrete and a group (n=12) kept on rubber mats after 12 weeks.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Concrete</th>
<th>Rubber Mat</th>
<th>P value+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Claw length*</td>
<td>70.4235</td>
<td>72.9073</td>
<td>0.7008</td>
</tr>
<tr>
<td>Growth**</td>
<td>4.3528</td>
<td>2.2452</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Wear**</td>
<td>2.3459</td>
<td>2.0714</td>
<td>0.9999</td>
</tr>
<tr>
<td>Sole thickness*</td>
<td>8.6117</td>
<td>9.1999</td>
<td>0.9923</td>
</tr>
<tr>
<td>Claw length</td>
<td>75.6216</td>
<td>75.9130</td>
<td>1.0000</td>
</tr>
<tr>
<td>Measure</td>
<td>Mean 1</td>
<td>SD 1</td>
<td>Mean 2</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------</td>
<td>------</td>
<td>--------</td>
</tr>
<tr>
<td>Growth</td>
<td>4.1836</td>
<td>0.2872</td>
<td>3.8645</td>
</tr>
<tr>
<td>Wear</td>
<td>3.3420</td>
<td>0.2610</td>
<td>3.6868</td>
</tr>
<tr>
<td>Sole thickness</td>
<td>10.9424</td>
<td>0.3265</td>
<td>11.1383</td>
</tr>
</tbody>
</table>

+ Measurements adjusted for week, lactation number, days in milk and cow weight.

* Measured at time 0

** Measured at time 2
Table 3. Comparison of claw length, wear, growth and sole thickness at the beginning and end of 12-week study period among a group of cows (n=12) kept on concrete and a group (n=12) kept on rubber mats.

| Week | Concrete | | | | | Rubber Mat | | | |
|------|----------|--------------|--------------|--------------|--------------|
| 0    | Length of claw | 70.4235 | 0.8301+ | 75.6216 | 0.8301 | <0.0001 | Length of claw | 72.9073 | 0.8301 | x<.0001 |
|      | Wear | 2.3459 | 0.2610 | 3.3420 | 0.2610 | 0.2244 | Wear | 2.0714 | 0.2610 | 3.6868 | 0.2610 | 0.0008 |
|      | Growth | 4.3528 | 0.2872 | 4.1836 | 0.2872 | 1.0000 | Growth | 2.2452 | 0.2872 | 3.8645 | 0.2872 | 0.0017 |
|      | Sole thickness | 8.6117 | 0.3265 | 10.9424 | 0.3265 | <.0001 | Sole thickness | 9.1999 | 0.3265 | 11.1383 | 0.3265 | <.0001 |

+ measurements adjusted for week, lactation number, days in milk and cow weight.