

The effects of different flooring types on the behavior, health, and welfare of finishing beef steers¹

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ABSTRACT: Raising beef cattle on concrete floors can negatively impact their welfare by increasing joint swelling and body lesions, as well as abnormalities in resting behavior and postural changes. We hypothesized that the addition of rubber mats to concrete pens would improve beef cattle welfare by improving performance, health, hygiene, and resting behavior. Forty-eight crossbred Angus steers were housed in pens of 4 and randomly assigned to a single flooring treatment: (1) fully slatted concrete (CON), (2) fully slatted rubber mat (SLAT), or (3) solid rubber mat (SOLID; 60% of pen floor) from 36 to 48 wk of age. Weight, ADG, lesions, gait score, joint swelling, and animal and pen cleanliness were collected every 2 wk. Behavioral time budgets and frequency of postural changes (an indicator of floor traction and comfort) were collected at 0, 6, and 12 wk. No differences in weight gain or ADG were observed. Steers on SOLID flooring (0.80 ± 0.08) showed increased lesions compared to SLAT (0.38 ± 0.08) and CON (0.37 ± 0.08 ; both, $P = 0.05$); however, there was no difference between SLAT and CON. SLAT steers (1.69 ± 0.04) showed a reduced gait score compared to SOLID (1.95 ± 0.04) and CON (1.98 ± 0.04 ; both,

$P < 0.05$), but SOLID and CON did not differ. Steers on SLAT flooring had less joint swelling (both knees and hocks) compared to SOLID and CON (all comparisons, $P < 0.05$), but SOLID and CON did not differ. Steers on SOLID (3.64 ± 0.05) flooring were dirtier than those on SLAT (2.27 ± 0.05) and CON (2.19 ± 0.05 ; both, $P < 0.001$), whereas SLAT and CON were similar. Additionally, SOLID and SLAT pens were less clean than CON pens ($P < 0.001$ and $P = 0.094$, respectively), and SOLID was less clean than SLAT ($P < 0.001$). Time budget behavior was affected by treatment ($P = 0.043$), where SOLID differed from CON and SLAT (both, $P < 0.05$). Steers on SOLID flooring preferred to rest on the rubber mat vs. slatted concrete ($P = 0.001$). Steers on SLAT flooring changed their posture more frequently than those on SOLID and CON flooring (both, $P < 0.05$), but SOLID and CON did not differ. Compared to CON steers, SOLID steers showed an increase in lesions and a reduction in cleanliness, whereas SLAT steers showed a decrease in gait score and joint swelling and an increase in postural changes. Combined, these data suggest that the addition of slatted rubber mats to concrete pens may improve beef cattle welfare.

Key words: animal welfare, beef steer, behavior, health, preference, rubber mat

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INTRODUCTION

Housing cattle on concrete has been linked to increased lesions and joint swelling (Rushen et al., 2007; Schulze Westerath et al., 2007), reduced claw health (Platz et al., 2007), and alterations in locomotion (Rushen and de Passille, 2006; Schutz and Cox, 2014). Concrete flooring can cause abnormal standing, lying, and transitional movements, as well as reduced traction, which can lead to injuries (Wierenga, 1987; Lidfors, 1989; Absmanner et al., 2009; Cozzi et al., 2013). Alterations in standing and lying behavior and postural changes, which are indicative

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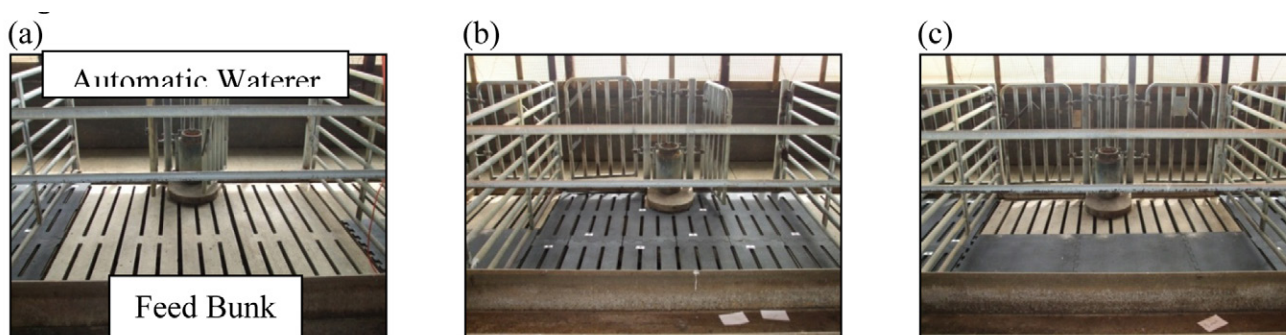


Figure 1. Photographs of experimental pens: (a) fully slatted concrete (CON, $n = 4$), (b) fully slatted rubber mat (SLAT, $n = 4$), and (c) solid rubber mat covering 60% of the pen floor (SOLID, $n = 4$). Each pen (3.05×3.05 m), equipped with an automatic waterer and feed bunk, housed four 9-mo old crossbred Angus steers for 12 wk.

of reduced comfort, have been observed in cattle housed on concrete compared to alternative flooring (Wierenga, 1987; Lidfors, 1989; Haley et al., 2001; Cozzi et al., 2013). When given the choice, cattle prefer other flooring substrates, such as straw, wood chips, or rubber mats, to concrete (Herlin, 1997; Lowe et al., 2001a; Manninen et al., 2002; Schutz and Cox, 2014).

In the dairy industry, there is an emphasis on “cow comfort,” with many researchers investigating flooring alternatives to improve animal health, hygiene, and welfare (e.g., Norring et al., 2008; Haufe et al., 2009; Ahrens et al., 2011; Fjeldaas et al., 2011; Schutz and Cox, 2014). Alternative flooring includes straw, sand, wood chips, rubber mats, mattresses, and mastic asphalt. Flooring alternatives have the potential to improve animal soundness and longevity through improvements in leg and joint health and function (Rushen and de Passillé, 2006; Flower et al., 2007; Onyiro and Brotherstone, 2008; Eicher et al., 2013), which may have an economic impact for producers.

Research into improving flooring comfort for finishing beef cattle has been frequently overlooked. Cozzi et al. (2013) suggests that the lack of research on alternative flooring for beef steers is due to economic constraints and the short time that beef cattle spend in finishing units compared to dairy cattle. Thus, a need exists to examine alternative flooring options for U.S. beef cattle, as concrete floors are still used in finishing and research facilities. Therefore, the aim of this study was to compare the effects of different types of flooring on beef cattle performance and welfare. We hypothesized that the addition of rubber mats to concrete pens would improve finishing steer welfare by positively impacting growth, leg health, hygiene, and behavior.

MATERIALS AND METHODS

All experimental procedures were approved by the Purdue University Animal Care and Use Committee (PACUC approval number 08-085). This experiment

lasted for a total of 12 wk from July through September of 2008.

Animals, Experimental Design, and Husbandry

A total of 48 crossbred Angus steers (9 mo old) were used in this study. At the start of the experiment, all steers were weighed (374.1 ± 27.5 kg; mean \pm SD) and sorted into 12 groups of 4, which were balanced for weight. Each group was randomly assigned to 1 of 3 flooring treatments ($n = 4$ per treatment): fully slatted concrete (CON), fully slatted rubber mat (SLAT), or solid rubber mat covering 60% of the pen floor (SOLID). All groups were housed in slatted (slat width 10.16 cm, gap width ranging from 1.91 to 3.81 cm) concrete pens (3.05×3.05 m), where SLAT and SOLID had the addition of textured rubber flooring (Ani-mat Inc., Sherbrooke, Quebec, Canada). The SLAT mat covered the entire pen floor and consisted of interlocking rubber sheets ($3.05 \text{ m} \times 3.05 \text{ m} \times 1.91 \text{ cm}$) that were secured with metal hardware, whereas SOLID was one complete sheet of rubber ($3.05 \text{ m} \times 1.83 \text{ m} \times 1.91 \text{ cm}$) that was located directly behind the concrete feed bunk and opposite the automatic waterer (Fig. 1). All experimental pens, including a pen reserved for video equipment, were located in the same barn and separated by standard livestock gates (3.03×1.52 m). An alley was located directly behind the pens, allowing for the movement of the cattle for data collection. Barn temperatures were mitigated via adjustable curtains present on both sides of the building. The steers had ad libitum access to both water and a standard corn-based finisher diet (DM 68.6%, CP 13.6%, and NE_g 0.56), which was replenished daily by the farm staff. In addition, farm employees observed the steers twice daily for overall health.

Animal and Pen Measures

Trained assessors, including experimenters and animal care staff, consistently scored the same measures throughout the experiment. Live weights were collected

Table 1. Scoring system for assessing steer and pen cleanliness

Scale Score	Description
Steer	1 <10% of body surface covered in manure
	2 >10%–25% of body surface covered in manure
	3 >25%–50% of body surface covered in manure
	4 >50%–75% of body surface covered in manure
	5 >75% of body surface covered in manure
Pen	0 Unused
	1 Clean, little manure on the floor
	2 Mounding manure in the corners
	3 Floor completely covered and wet with manure (<1.27 cm deep)
	4 Floor completely covered and wet with manure (~1.27 cm deep)
5 Floor completely covered and wet with manure (>1.27 cm deep)	

for all steers at the start of the experiment (without feed or water restriction) and every 2 wk thereafter, until the end of the study. In addition, lesion score (including the entire body and legs), gait score as an indicator of lameness, joint swelling, and cleanliness scores (steers and pen) were obtained every 2 wk throughout the 12-wk study. Lesion scores (scale range 0 to 5, where a score of 0 represents no lesion and a score of 5 represents an open cut; Norring et al., 2008), gait scores (scale range 1 to 5, where a score of 1 represents no lameness and a score of 5 represents a severely lame and hindered animal; Flower and Weary, 2006), cleanliness of the steers and pens (Table 1), and joint swelling (Table 2) were obtained through visual inspection by trained individuals and in accordance with predetermined scales. Hock swelling scores were only recorded from wk 6 through wk 12 of the experiment.

Behavioral Observations

Every 2 wk, in conjunction with the measures described above, steer behavior in the home pens was recorded for 24-h using time-lapse video (additional low lighting was provided at night). Because of equipment shortages, only half of the pens could be recorded at one time, necessitating the employment of 2 recording days per data collection period, where the first pen to be recorded was alternated throughout the study. A black-and-white camera (Panasonic 338 WVBP330, Panasonic, Secaucus, NJ) was mounted on the ceiling between every 2 pens. The output was recorded using a time-lapse VCR (Panasonic AGTL950P, Panasonic) and a multiplexer (Panasonic WJ-FS216, Panasonic) in 48-h mode.

The steers were marked for identification on the video using a 50:50 mixture of latex and oil-based paint, which was reapplied as necessary throughout the study. The videos from wk 0, 6, and 12 were analyzed for time budget information by 1 experienced observer using instantaneous scan sampling every 10 min. For each time

Table 2. Scoring system for assessing knee and hock swelling

Score	Description
0	No swelling visible
1	Slight swelling visible
2	Half of a baseball-sized swelling (~3.75 cm)
3	Baseball-sized swelling (~7.5 cm)
4	Between baseball- and softball-sized swelling
5	Softball-sized swelling (~10 cm)

point, the behavior of each steer in the pen was recorded (Table 3). A subset of video was analyzed at 1, 5, and 10 min intervals for all flooring treatments and behaviors. For the behaviors of most importance to this study, such as standing and lying, all time points showed greater than 90% agreement (range 92.29% to 99.72%) for all treatments. Behaviors of lower importance to the aim of this study, such as drinking, for which there were no predictions as to how the flooring treatment would impact the behaviors, showed less agreement (72.19% to 97.76%) across all sampling time points. However, as the scoring of behaviors of most interest to this study remained robust at the larger sampling window, 10 min sampling was employed for video analysis. In addition, the type of flooring being used by the steers in the SOLID pen (i.e., the solid mat or slatted concrete portion of the pen) was recorded to gather data on flooring preference. After the collection of time budget data, the frequency of postural changes (lying to standing or standing to lying) during a 24-h period was determined at wk 0, 6, and 12 of the experiment.

Statistical Analysis

Data analysis for all measures was conducted using the MIXED procedure of the Statistical Analysis Systems software (version 9.2; SAS Inst. Inc., Cary, NC). Data were analyzed as a 2-way (treatment × week) repeated measures ANOVA, where the experimental unit was a pen of 4 steers. However, time budget data (treatment × week × behavior) and the flooring preference of SOLID steers (week × behavior × floor) were analyzed as a 3-way ANOVA. The behaviors “kneeling” and “other” were removed from the time budget data set because of infrequent observation. In addition, “drinking” and “feeding” were removed from the flooring preference data set as these behaviors could only be performed on 1 flooring surface because of the layout of the pen (slatted concrete or the solid mat, respectively). Degrees of freedom in our statistical models were as follows: treatment, 3 (CON, SLAT, SOLID), and week, 7 (the majority of the measures were obtained at wk 0, 2, 4, 6, 8, 10, and 12). The exceptions include 1) ADG,

Table 3. Descriptive ethogram used to record behavioral time budget data

Behavior	Definition
Drinking	Head in or above paddle waterer
Feeding	Head in or above feed bunk
Grooming	Licking self or pen mate
Kneeling	Knees touching the ground while rear end is supported by hind legs; transitional behavior before standing or lying
Lying	Includes lying sternally and laterally
Standing	Standing inactive and supported by at least 3 legs
Other	Any other behaviors not listed

which is only 6 time points because there is no baseline value at wk 0 for this measure, 2) hock swelling, which was only measured at wk 6, 8, 10, and 12, and 3) time budget behavior and postural changes data, which were only measured at wk 0, 6, and 12. In addition, time budget behaviors, 5 (drinking, feeding, grooming, lying, and standing), flooring preference, 5 (grooming, kneeling, lying, standing, and other), and flooring type, 2 (concrete portion of the pen or SOLID rubber mat portion).” Data were transformed as necessary to meet the assumptions of the test (homogeneity of variance, normality of error and linearity). Transformations include lesion score (log), knee swelling (square root), hock swelling (log), steer cleanliness (square root), time budget (angular), and flooring preference (log). Statistical significance was accepted at $P < 0.05$ and statistical trends at $P < 0.10$. Post-hoc paired contrasts were used to further examine significant main and interactive effects. Unless otherwise stated, data are presented as untransformed least squares means \pm SEM.

RESULTS

Growth Performance

Weight Gain. Repeated measures ANOVA revealed an effect of week ($F_{6,54} = 443.40$; $P < 0.001$), where all steers gained weight throughout the course of the study (data not shown). On average, steers weighed 334.99 ± 1.86 kg at the start of the experiment (wk 0) and 467.33 ± 1.86 kg by the end of the study (wk 12). However, there was no effect of flooring treatment ($F_{2,9} = 0.20$; $P = 0.825$) or a treatment \times week interaction ($F_{12,54} = 1.32$; $P = 0.235$) for weight gain.

ADG. Similar to the results for weight gain, there was an effect of week ($F_{5,45} = 27.64$; $P < 0.001$), where ADG differed over time (data not shown). On average, steers showed an ADG of 1.88 ± 0.09 at wk 2 and 2.18 ± 0.09 at the end of the study (wk 12). However, there was no effect of flooring treatment ($F_{2,9} = 0.06$; $P = 0.940$) or a treatment \times week interaction ($F_{10,45} = 1.47$; $P = 0.182$) for ADG.

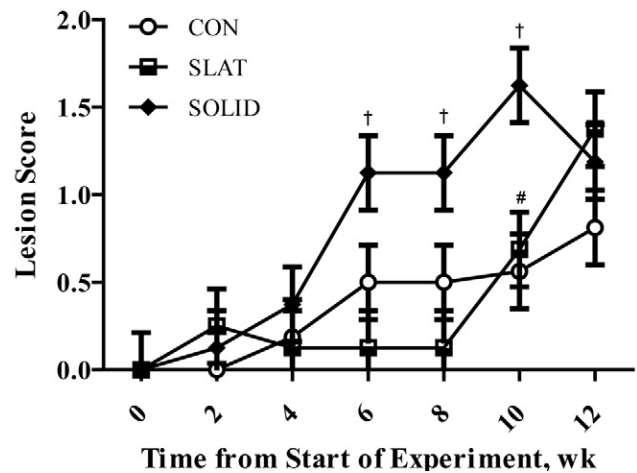


Figure 2. Lesion score. Incidence of leg lesions (scale range 0 to 5, where a score of 0 represents no lesion and a score of 5 represents an open cut; Norring et al., 2008) for steers housed on different types of flooring throughout the 12-wk study: fully slatted concrete (CON), fully slatted rubber mat (SLAT), or solid rubber mat covering 60% of the pen floor (SOLID). Each data point represents the average (least squares means \pm SEM) lesion score per pen ($n = 4$ pens/treatment). Contrasts were used to separate treatment means at each time point. For all comparisons $P < 0.05$: #differences between CON and SOLID, and †differences between SLAT and SOLID.

Health and Cleanliness

Lesion Score. The incidence of leg lesions was affected by flooring treatment ($F_{2,9} = 6.95$; $P = 0.015$) and week of the experiment ($F_{6,54} = 17.62$; $P < 0.001$). Post hoc contrasts revealed that steers on SOLID flooring showed increased lesions compared to steers on SLAT and CON flooring ($P = 0.007$ and $P = 0.016$, respectively); however, there was no difference between SLAT and CON ($P = 0.637$). In addition, there was a trend for lesion scores to show a treatment \times week interaction ($F_{12,54} = 1.94$; $P = 0.05$), with SOLID steers having greater lesions (Fig. 2).

Gait Score. Steer lameness, as indicated by gait score, was impacted by flooring treatment ($F_{2,9} = 6.55$; $P = 0.018$). Post hoc tests showed that steers on SLAT flooring had a lower overall gait score (1.69 ± 0.06) compared to those on SOLID (1.95 ± 0.06 ; $P = 0.015$) and CON (1.98 ± 0.06 ; $P = 0.01$) flooring, but steers on SOLID and CON flooring did not differ ($P = 0.813$). Additionally, gait score was affected by week of the experiment ($F_{6,54} = 9.08$; $P < 0.001$), where the gait scores increased in severity over time regardless of treatment (data not shown). On average, steers showed a gait score of 1.54 ± 0.07 at wk 0 and 2.16 ± 0.07 at wk 12. However, there was no treatment \times week interaction for gait score in this experiment ($F_{12,54} = 0.98$; $P = 0.475$).

Knee Swelling. Repeated measures ANOVA revealed an effect of flooring treatment ($F_{2,9} = 8.34$; $P = 0.009$) on knee swelling scores. Post hoc contrasts showed that steers on SLAT flooring had less swelling compared to SOLID ($P = 0.036$) and CON ($P = 0.003$) steers; how-

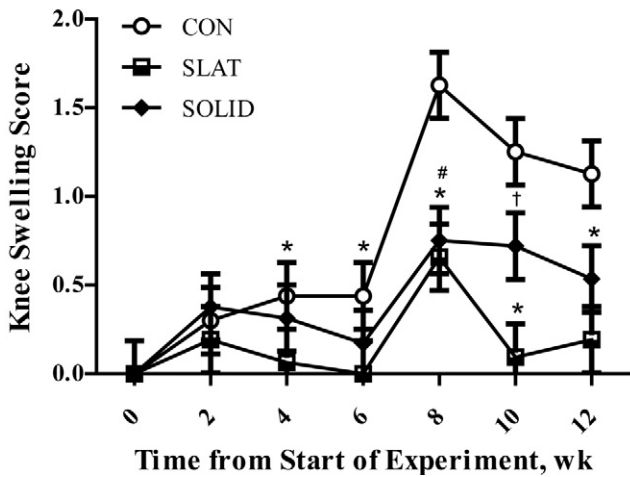


Figure 3. Knee swelling. Incidence of knee swelling (scale range 0 to 5, where a score of 0 represents no swelling and a score of 5 represents softball-sized swelling [~ 10 cm]) for steers housed on different types of flooring throughout the 12-wk study: fully slatted concrete (CON), fully slatted rubber mat (SLAT), or solid rubber mat covering 60% of the pen floor (SOLID). Each data point represents the average (least squares means \pm SEM) knee swelling score per pen ($n = 4$ pens/treatment). Contrasts were used to separate treatment means at each time point. For all comparisons $P < 0.05$: *differences between CON and SLAT, #differences between CON and SOLID, and †differences between SLAT and SOLID.

ever, there was no overall difference between SOLID and CON steers ($P = 0.145$). Additionally, there was an effect of week ($F_{6,54} = 25.72$; $P < 0.001$) and a treatment \times week interaction ($F_{12,54} = 2.19$; $P = 0.026$), with SLAT steers showing less swelling over time (Fig. 3).

Hock Swelling. Similar to the results for knees, there was an effect of treatment ($F_{2,9} = 8.87$; $P = 0.007$) on hock swelling scores, where SLAT steers had a lower score (0.1456 ± 0.098) than SOLID (0.51 ± 0.10 ; $P = 0.009$) and CON (0.62 ± 0.10 ; $P = 0.004$) steers, but SOLID and CON did not differ ($P = 0.585$). In addition, there was an effect of week of the experiment on hock swelling ($F_{3,27} = 6.90$; $P = 0.001$), where steers showed a peak in swelling at wk 8 of the experiment (data not shown). However, unlike knee swelling, there was no treatment \times week interaction observed for this measure ($F_{6,27} = 1.05$; $P = 0.416$).

Steer Cleanliness. Statistical analysis revealed an effect of both week ($F_{6,54} = 100.01$; $P < 0.001$) and treatment ($F_{2,9} = 75.12$; $P < 0.001$) on steer cleanliness. As the experiment progressed, all of the animals, regardless of flooring treatment, became dirtier. The SOLID steers were the least clean compared to SLAT and CON steers (both, $P < 0.001$), but SLAT and CON were not different from each other ($P = 0.522$). Additionally, there was a significant treatment \times week interaction for this measure ($F_{12,54} = 7.27$; $P < 0.001$; Fig. 4a).

Pen Cleanliness. Not surprisingly, similar results for pen cleanliness were observed in this experiment. There was an effect of week ($F_{6,54} = 132.17$; $P <$

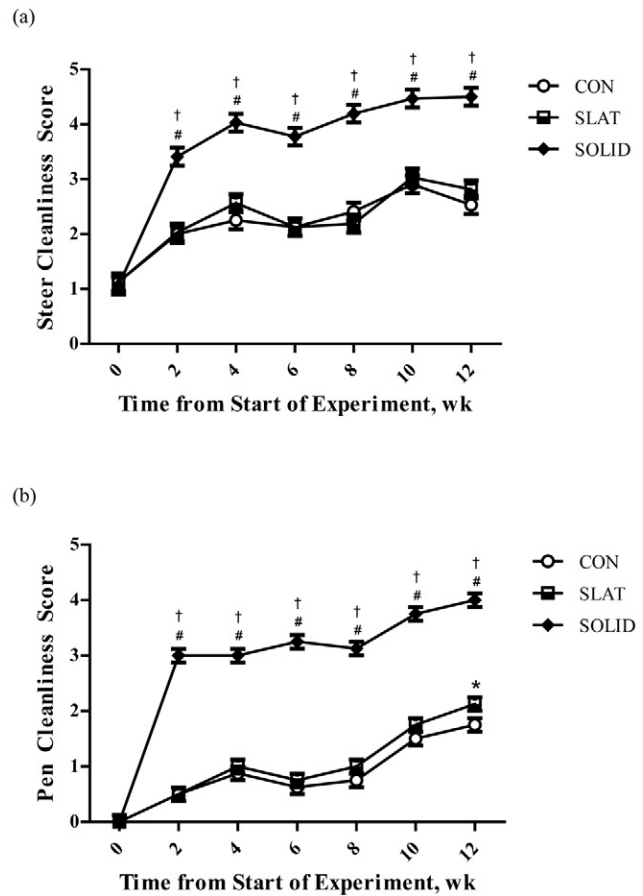


Figure 4. Cleanliness scores. (a) Steer cleanliness (scale range 1 to 5, where a score of 1 represents $<10\%$ of the body surface covered in manure and a score of 5 represents $>75\%$ of the body surface covered in manure) and (b) pen cleanliness (scale range 0 to 5, where a score of 0 represents an unused pen and a score of 5 represents a floor completely covered and wet with manure [>1.27 cm deep]) scores for steers housed on different types of flooring throughout the 12-wk study: fully slatted concrete (CON), fully slatted rubber mat (SLAT), or solid rubber mat covering 60% of the pen floor (SOLID). In both graphs, each data point represents the average (least squares means \pm SEM) steer or pen cleanliness score per pen ($n = 4$ pens/treatment). Contrasts were used to separate treatment means at each time point. For all comparisons $P < 0.05$: *differences between CON and SLAT, #differences between CON and SOLID, and †differences between SLAT and SOLID.

0.001) and treatment ($F_{2,9} = 342.13$; $P < 0.001$) on pen cleanliness. As the experiment progressed, all of the pens became dirtier. SOLID and SLAT pens were less clean than CON pens ($P < 0.001$ and $P = 0.094$, respectively), and SOLID was less clean than SLAT ($P < 0.001$). Additionally, there was a significant treatment \times week interaction for this measure ($F_{12,54} = 21.49$; $P < 0.001$; Fig. 4b).

Behavioral Measures

Time Budget Behaviors. There was a main effect of flooring treatment on the behavioral time budget data ($F_{2,9} = 4.56$; $P = 0.043$), where the behavior of steers on SOLID flooring differed significantly from that of steers on CON ($P = 0.02$) or SLAT flooring

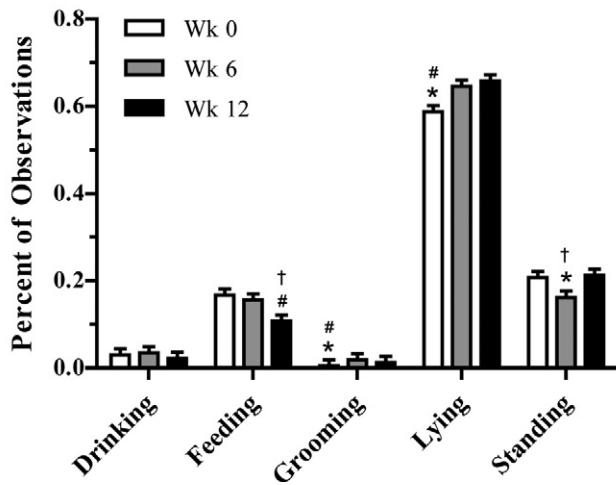


Figure 5. Time budget behaviors. The observed proportion of time spent in different behaviors (drinking, feeding, grooming, lying, or standing) over the course of a 24-h period throughout the 12-wk study on fully slatted concrete (CON), fully slatted rubber mat (SLAT), or solid rubber mat covering 60% of the pen floor (SOLID). Each bar represents the average (least squares means \pm SEM) proportion of time spent performing each behavior per pen ($n = 4$ pens/treatment). Contrasts were used to separate treatment means. For all comparisons $P < 0.05$: *differences between wk 0 and wk 6, #differences between wk 0 and wk 12, and †differences between wk 6 and wk 12.

($P = 0.043$), whereas CON and SLAT ($P = 0.657$) did not differ. In addition, week ($F_{2,18} = 2.69$; $P = 0.095$), behavior ($F_{4,36} = 1066.49$; $P < 0.001$), and week \times behavior ($F_{8,72} = 8.15$; $P < 0.001$) were all significant factors. The behavior of the steers, particularly their feeding, grooming, lying, and standing behavior, differed throughout the course of the experiment (Fig. 5). However, treatment \times week ($F_{4,18} = 0.14$; $P = 0.965$), treatment \times behavior ($F_{8,36} = 1.66$; $P = 0.141$), and treatment \times week \times behavior ($F_{16,72} = 0.59$; $P = 0.881$) were not different due to flooring treatment.

Flooring Preference of SOLID Steers. The proportion of time steers spent performing different behaviors ($F_{2,6} = 292.17$; $P < 0.001$), as well as the type of flooring used ($F_{1,3} = 42.88$; $P = 0.007$), varied for the SOLID flooring treatment (main effect; data not shown). More importantly, the interaction of behavior \times floor showed a significant effect ($F_{2,6} = 8.33$; $P = 0.019$), demonstrating that steers performed specific behaviors while in contact with different flooring surfaces. In particular, steers spent significantly more time lying on the solid rubber mat compared to the slatted concrete flooring ($48.83\% \pm 2.10\%$ vs. $18.06\% \pm 2.10\%$, respectively; $P = 0.001$) and more time grooming on the solid rubber mat than on the slatted concrete flooring as well ($1.06\% \pm 2.10\%$ vs. $0.50\% \pm 2.10\%$, respectively; $P = 0.001$). However, standing behavior did not differ in relation to flooring type ($9.94\% \pm 2.10\%$ for solid rubber mat vs. $8.66\% \pm 2.10\%$ for slatted concrete; $P = 0.358$). In addition, week ($F_{2,6} = 1.04$; $P = 0.411$), week \times behavior ($F_{4,12} = 1.27$; $P = 0.337$), week \times

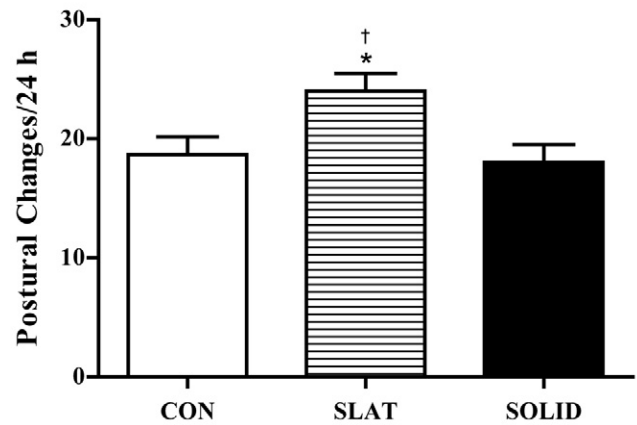


Figure 6. Postural changes. Frequency of postural changes (defined as lying to standing or standing to lying) over a 24-h period for steers housed on different types of flooring: fully slatted concrete (CON), fully slatted rubber mat (SLAT), or solid rubber mat covering 60% of the pen floor (SOLID). Each data point represents the average (least squares means \pm SEM) number of postural changes per pen ($n = 4$ pens/treatment). Contrasts were used to separate treatment means. For all comparisons $P < 0.05$: *differences between CON and SLAT, and †differences between SLAT and SOLID.

area ($F_{2,6} = 0.47$; $P = 0.649$), and week \times behavior \times area ($F_{4,12} = 0.55$; $P = 0.701$) were not significant.

Postural Changes. Flooring treatment impacted the frequency of postural changes exhibited by steers (ANOVA: $F_{2,9} = 4.86$; $P = 0.037$; Fig. 6), where those on SLAT flooring showed more postural changes than those on SOLID ($P = 0.019$) and CON ($P = 0.032$) flooring, but steers on SOLID and CON flooring did not differ ($P = 0.766$). In addition, there was an effect of week on this measure (ANOVA: $F_{2,18} = 7.94$; $P = 0.003$), where postural changes were greater at wk 6 (22.75 ± 1.19) and wk 12 (20.46 ± 1.19) compared to the start of the experiment (wk 0: 17.48 ± 1.19 ; $P = 0.001$ and $P = 0.072$, respectively). However, there was not a treatment \times week interaction (ANOVA: $F_{4,18} = 1.59$; $P = 0.22$) observed for this measure.

DISCUSSION

Although there is a large body of work investigating flooring substrates for dairy cattle, there seems to be little attention directed to the impact of alternative flooring on finishing beef cattle welfare. Therefore, our aim was to investigate the impact of alternative flooring substrate on finishing beef steer growth, health, hygiene, and behavior. On the basis of the data presented here, we conclude that SLAT may offer an improved flooring system for the welfare of finishing beef steers compared to CON or SOLID (covering 60% of the pen floor).

In this study, SLAT steers showed a decrease in lameness, as indicated by gait score, and a decrease in knee and hock swelling compared to steers housed on SOLID and CON flooring. Improvements in locomotion and leg health have been observed in oth-

er studies where rubber mats (Rushen et al., 2007; Schulze Westerath et al., 2007; Graunke et al., 2011; Eicher et al., 2013), sand (Norrington et al., 2008), wood chips (Schutz and Cox, 2014), mastic asphalt (Haufe et al., 2012), or straw (Livesey et al., 2002; Schulze Westerath et al., 2007) have been provided to cattle. In addition, a review by Wechsler concluded that slatted floors with rubber covering were a suitable alternative to standard concrete slats because of improvements in animal behavior and reduced leg lesions (Wechsler, 2011). Although SLAT steers showed a reduced overall gait score compared to the other flooring treatments, the rubber mats were unable to prevent an increase in gait score throughout the course of the 12-wk study. It is likely that with increasing body weight over time, additional stresses on the steers' joints and legs could not be overcome by the rubber mat alone.

In addition to improvements in leg and joint health and function, SLAT steers showed an increase in postural changes, which could be due to properties of the rubber flooring, such as increased traction and footing (Flower et al., 2007) or reduced discomfort (Haley et al., 2001; Rushen et al., 2007). Flooring type has been shown to alter standing-up and lying-down movements (Wierenga, 1987; Lidfors, 1989; Cozzi et al., 2013), preparation time for postural changes (Lidfors, 1989; Herlin, 1997), and the length of lying bouts (Haley et al., 2001; Rushen et al., 2007; Norring et al., 2008). For example, fattening bulls showed fewer postural changes, increased investigation of the lying area before lying down, and longer lying intervals when housed on slatted floors compared to deep litter (Lidfors, 1989). In addition, a lower number of lying and standing transitions were seen in fattening bulls housed on fully slatted concrete compared to a rubber mattress (Cozzi et al., 2013). In this study, it is unknown if improved joint health lead to an increased ability or willingness of the steers to change posture or, alternatively, if alterations in postural changes lead to improvements in joint health and locomotion.

Although the flooring substrate used in the SOLID pens was the same material used for the SLAT pens, similar improvements in leg health and function were not observed. The solid rubber mat covered approximately 60% of the pen (near the feed bunk), leaving the remainder of the pen as slatted concrete (near the waterer). Compared to SLAT and CON, the SOLID pens were extremely dirty, with the floors being completely covered with wet manure, which resulted in the animals within these pens having overall reduced cleanliness. Interestingly, the SLAT pens showed a slight trend to be dirtier than CON pens, but this did not translate to a dirtier animal. Lowe et al. (2001b) also found that beef cattle housed on rubber mats were dirtier, retaining more excrement

on their coats, than cattle housed on alternative flooring substrates, including straw and concrete. In addition, no improvements in cleanliness were observed when slatted concrete was covered with slatted rubber mats in a dairy facility (Ahrens et al., 2011), and dairy cattle in facilities with rubber mats or mattresses were dirtier than those provided sand (Andreasen and Forkman, 2012). Pen and steer cleanliness are important issues, as an unclean environment leads to unclean animals that have a lower market value. Extremely dirty cattle may be turned away from slaughter facilities because of increased risk of meat contamination from fecal bacteria on the hide or may be reduced in price to offset labor costs (Lowe et al., 2001b; Schulze Westerath et al., 2007).

In addition, SOLID steers showed increased leg lesions. This is in contrast to data from Platz et al. (2007), in which fattening bulls housed in a pen with a rubber mat that partially covered the flooring surface showed reduced lesions. In our study, the increased lesions may have been due to reduced traction and increased slippage in these dirty SOLID pens. This suggestion is supported by evidence from Rushen and de Passillé (2006), who showed that the addition of slurry to a walkway increased the frequency of slipping in dairy cattle. Alternatively, the leg lesions may have been caused by excessive excrement on the legs leading to skin irritation and hair loss. The dirtiness of the pen may have also impacted the postural change data. SOLID steers showed a significantly lower number of postural changes than SLAT steers, which may have been due to lower traction on the excrement-covered mat and a reduced ability to change posture.

Despite these issues, finishing steers preferred to rest on the solid rubber mat in the SOLID pens, spending approximately 75% of their lying time on the mat compared to the slatted concrete. In a similarly designed study, fattening bulls preferred the rubber-coated area of their pen compared to slatted concrete as well (Platz et al., 2007). However, the flooring preference data from the current study must be taken with caution for 2 reasons. First, 60% of the pen floor was covered with the solid rubber mat, leading to an imperfect preference experiment, in which the animal's choice is already biased toward the rubber mat. Second, not all steers could lie on the mat at 1 time, especially as the animals increased in size throughout the experiment, which biases the preference data away from the rubber mat. Given these limitations, it is still interesting that the SOLID cattle showed a preference for resting on the mat despite no improvements in performance, health, hygiene, or behavior over CON flooring. It may be that rubber mats, in any form, provide some benefit to the animal (e.g., increased cushioning) that was not apparent in our measurements and was confounded by the reduced

cleanliness of the pen. Although the current study did not measure claw lesions, solid rubber mats have been shown to reduce laminitis-related lesions in dairy cattle, such as white line fissures, hemorrhages of the white line and sole, and the presence of double soles (Fjelddas et al., 2011). If the mats had been cleaned daily, as is practiced in many dairy facilities, we may have seen similar improvements in gait score and joint swelling as observed for the SLAT treatment.

Although flooring substrate had a large impact on health, hygiene, and postural changes, there was no impact of flooring treatment on time budget behavior or performance data. Time budget behavior data varied over time, where feeding decreased and lying increased over the course of the experiment, but there was no effect of flooring treatment on these measures. This finding is in contrast to other studies (e.g., Fregonesi et al., 2004; Norring et al., 2008; Absmanner et al., 2009), in which the percentage of time spent feeding, standing, and lying were altered by the flooring provided. In addition, weight gain and ADG were similar throughout the study for SLAT, SOLID, and CON steers. This finding agrees with the results of Lowe et al. (2001b) and Graunke et al. (2011), who found no differences in live-weight or carcass gains for cattle raised on slatted rubber floors compared to other flooring alternatives. These authors also found no treatment differences for carcass composition or meat quality (Lowe et al., 2001b; Graunke et al., 2011). In addition, time spent eating was not affected by the provision of rubber flooring in a study with dairy cattle (Fregonesi et al., 2004). However, in contrast, Cozzi et al. (2013) found that young bulls provided a rubber mattress showed improvements in ADG compared to those housed on fully slatted concrete floors. On the basis of performance data alone, this study indicates no differences between flooring treatments. Although not addressed in this study, one could speculate that improvements in leg and joint health could increase longevity and reduce culling, leading to reduced economic loss for the producer in the long term.

Combined, these data demonstrate that the addition of slatted rubber mats to concrete pens improves finishing beef steer locomotion, leg and joint health, and alterations in behavior that are indicative of increased traction and reduced discomfort. Therefore, slatted rubber mats may offer a flooring alternative to improve the welfare of beef cattle housed in systems with concrete flooring.

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