Observations on the design and use of footbaths for the control of infectious hoof disease in dairy cattle

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A B S T R A C T

A survey of 65 freestall-housed dairy herds in five different countries, with an average of 1023 milking cows, found that footbaths were used 1–4 times per day for 1–7 days per week, with between 80 and 3000 cows passing through the bath between chemical changes. The most common agents used were copper sulfate (41/65) and formalin (22/65). Twenty-seven herds (42%) used more than one chemical. The median footbath measured 2.03 m long by 0.81 m wide, and was filled to a depth of 0.11 m with a volume of 189 L (range 80–1417 L).

An observational behavioral study was conducted using a custom-designed footbath to test four different bath dimensions, with two different step-in heights. The number of immersions per rear foot was counted for each footbath design for each cow passing through the bath on two consecutive days. While a higher step-in height significantly increased the number of foot immersions, the effect was small compared to the effect of length. The probability of each rear foot receiving at least two immersions reached 95% at a bath length of 3.0 m, and a significant increase in the frequency of three and four immersions per foot was observed between 3.0 and 3.7 m. In order to optimize the number of foot immersions per cow pass, while limiting the footbath volume, this study recommends a bath 3.0–3.7 m long, 0.5–0.6 m wide, with a 28 cm step-in height.

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Introduction

Infectious causes of lameness in dairy cattle remain common world-wide in intensively managed systems (Blowey, 2005). Heel horn erosion (slurry heel), (papillomatous) digital dermatitis (Mortellaro’s disease, heel warts) and interdigital necrobacillosis (foul-in-the-foot, footrot) commonly affect cattle maintained in environments where foot hygiene is poor, creating low oxygen tension, and a constant moist environment on the epidermis of the skin adjacent to the claw horn, which is ideal for infection and disease (Berry, 2001).

In freestall (cubicle) housed dairy herds, use of a footbath with a variety of different antibacterial agents is commonplace and the centerpiece of many on-farm approaches to the control of infectious hoof disease. Given the high prevalence of lameness in the dairy industry and the significant contribution to the overall problem through diseases such as digital dermatitis (Blowey, 2005), it is surprising to find that so little research has been invested in the operation of footbaths. The studies that have been performed have generally focused on the efficacy of different antibacterials, such as copper sulfate, zinc sulfate, formalin and antibiotics such as oxytetracycline, erythromycin and lincomycin (see review by Laven and Logue (2006)).

Of note in the product testing used in completion of footbath research, are the wide variation in methodologies between studies and farms. For example, the duration of the studies has ranged from 1 week to 6 months (Laven and Hunt, 2002; Manske et al., 2002), and the frequency of use has ranged from 1 to 5 days per week (Holzhauer et al., 2008; Döpfer et al., in press). Some studies have examined the efficacy of the footbath for treatment of cows with existing infections (see, for example, Laven and Hunt, 2002), rather than the prevention of infection in the entire group (e.g. Thomsen et al., 2008; Speijers et al., 2010; Teixeira et al., 2010). Two reports used a split bath and within-cow control (Manske et al., 2002; Thomsen et al., 2008), while others used a single bath and separate treatment and control groups of cows (Holzhauer et al., 2008; Speijers et al., 2010; Teixeira et al., 2010; Döpfer et al., in press). There is an obvious need to standardize footbath-testing methodology to provide comparable results across studies, and the design and frequency of use of the footbath should be included in that standardization.

The efficacy of a topical antibacterial agent against infectious hoof disease is likely to be influenced by the transfer of the chemical to the foot, and its contact time with the adjacent skin. This
will be largely determined by the design and layout of the footbath. Substantial differences in bath design exist between reported studies. For example, footbath length ranges between 1.5 m and 3.0 m across studies (e.g. Holzhauser et al., 2008; Teixeira et al., 2010). The impact of different footbath designs on the delivery of antibacterial chemicals to the feet as the cow passes through the bath needs to be explored.

The objectives of this study were, firstly, to measure and summarize the design and use of footbaths in order to examine the current scope of variation in freestall-housed dairy herds. Secondly, using the number of foot immersions received per cow pass as a primary outcome to optimize design of the footbath, we performed an observational behavioral study to determine the effect of different bath dimensions on delivery of chemical to the cow’s feet.

Material and methods

A survey of different footbath designs and practices of freestall housed dairy herds was performed using First Step software (Zinpro) and the technical field staff of Zinpro. First Step is a database program designed to capture and summarize risk factors for lameness in dairy herds based on 20 different risk assessors. The footbath assessor is used to summarize current footbath design and management on farms visited by field staff as part of their value added services to their nutrition clients worldwide. The clients selected had expressed an interest in receiving the service and were therefore not a true random sampling of dairy herds. The First Step files were uploaded and summarized in Excel (Microsoft) with one entry per farm for a total of 65 farms. The data collected included the footbath dimensions, the number of cow passes between chemical changes, the types of antibacterial agent used and the frequency of footbath use.

An observational behavioral study was carried out on a 550-cow commercial freestall-housed dairy herd. A single pen of approximately 90 Holstein milking cows was chosen as the study group, and the owner was asked to keep the group stable and be accustomed to it. The number of foot immersions for each rear leg of each cow was recorded over the two recording sessions for each design combination. An immersion was defined as a step in which the foot disappeared below the surface of the footbath solution. A minimum of 170 observations were recorded on each test day.

All data were summarized in Excel (Microsoft) and statistical analyses were performed in SAS (version 9.2; SAS Institute). The influence of footbath dimensions on delivery of chemical to the cow’s feet.

Results

The 65 freestall housed dairy herds surveyed averaged 1023 milking cows in size with a range from 100 to 4100 cows. The herds originated from five different countries (US, Spain, Japan, UK and New Zealand) and within the US, 12 different States were represented. A wide variety of antibacterials were used in the footbath, with 42% of herds using more than one agent in rotation. Copper sulfate was the most commonly used antibacterial, with 63% of herds using it at concentrations of between 1% and 10%, often in combination with an acidifying agent. Formalin was also common, used by 34% of surveyed herds at between 2% and 5% concentration. A proprietary liquid zinc chloride solution (Hoof-Zink: Garco) was used by 9% of herds. Antibiotics, including lincomycin and oxytetracycline, were used by only 5% of herds, and then only in the case of an outbreak of digital dermatitis.

Table 1 summarizes the footbath design and management survey data obtained. The median footbath measured 0.81 m wide, was 2.03 m long and was filled to a depth of 11 cm. Median capacity was 189 L, with a wide range from 80 to 1417 L. The median frequency of footbath use on the surveyed farms was once a day, with a range from one to four times daily, and 3 days per week with a range from 1 to 7 days. Median cow passes between chemical changes was 250, with a wide range from 80 to 3000 cow passes.

The mean (SD) number of rear foot immersions in footbaths of different dimensions is summarized in Fig. 1 for the observational behavioral study. As the footbath length increased, the number of immersions per rear foot also increased. At the shortest footbath length of 1.8 m, 51% (SD 4.7%) of rear feet received only one immersion and 46% (SD 1.6%) received two immersions per cow pass. The frequency of foot immersions was significantly influenced by both footbath length (P < 0.001) and step-in height (P < 0.001). However, the size of the effect of step-in height was relatively small compared to the impact of length (F statistic 13.1 compared to 102.2 respectively). The higher step-in height allowed for improved retention of the bath solution and was tolerated well by the cows, therefore, the 28 cm step-in was the only version tested for the two longest bath lengths.

The probability for each rear foot receiving at least two immersions is shown in Fig. 2. Greater than 95% probability of at least two immersions per rear foot was not achieved until the bath measured at least 3.0 m in length. A significantly greater number of foot immersions were observed in the 3.7 m bath compared to the 3.0 m bath, with a significant transition from 30% (SD 0.4%) to 56% (SD 1.6%) of feet receiving three immersions, and an increase in the number of feet with four or more immersions (P < 0.05).

Discussion

Although small in scale, this study highlights the variability in footbath design and management observed in freestall housed dairy herds world-wide, and given the paucity of scientific information related to footbath programs it is unsurprising. The survey herds were a select population requesting services from Zinpro Corporation, and the mean herd size of 1023 cows suggests that they represented larger more progressive production units.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Footbath dimensions</th>
<th>Volume of solution (L)</th>
<th>Frequency of use</th>
<th>Cow passes between solution changes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length (m)</td>
<td>Width (m)</td>
<td>Depth of fill (m)</td>
<td>Times per day</td>
</tr>
<tr>
<td>Median (range)</td>
<td>2.03 (1.57–4.55)</td>
<td>0.81 (0.30–3.51)</td>
<td>0.11 (0.05–0.18)</td>
<td>189 (80–1417)</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>2.25 (0.61)</td>
<td>1.05 (0.56)</td>
<td>0.11 (0.03)</td>
<td>281 (252)</td>
</tr>
</tbody>
</table>
Despite the general understanding that footbaths are extremely important in the control of infectious hoof disease (Blowey, 2005), guidance on their operation remains largely empirical. Copper sulfate and formalin dominate the agents used as antibacterials in footbaths despite the wide variety of options available, suggesting that producers believe that these agents remain cost effective and efficacious. This view is supported by recent research (Holzhauer et al., 2008; Speijers et al., 2010; Teixeira et al., 2010; Döpfer et al., in press), where 4% formalin and copper sulfate at concentrations of 2–5% were reported to provide effective control. Given the concerns regarding the use of antibiotics in production agriculture, it is comforting to see that at least in this small sub-set of herds, extra-label use in footbaths was uncommon, and limited to secondary use in the event of an outbreak of digital dermatitis.

Despite the general advice that footbaths should be used regularly to be effective (Blowey, 2005), there was a wide range of times per day and days per week of use. With problems associated with disposal of the chemicals used, perhaps the best advice for any given herd is to use the footbath as little as possible to maintain effective control over the incidence of infectious causes of lameness. In the surveyed herds, the median herd used a footbath once a day for three days a week, which is more frequent than many of the published studies that report efficacy at a frequency of 1–2 days per week (Holzhauer et al., 2008; Speijers et al., 2010; Teixeira et al., 2010). More work is required to optimize prevention strategies at least cost, limiting antibacterial use to the minimum required to obtain effective control.

The number of cow passes between solution changes varied widely between 80 and 3000 cows, with a median of 250 cows. Empirical advice for changing footbath solutions every 100–300 cows appears to be followed by the majority of farms, but is challenged on larger dairies, where this recommendation would require chemical changes for every pen of cows milked. Clearly there is a need for scientifically sound advice on when it is necessary to replenish the solution. Activity and effectiveness varies with the different antibacterial agent used, the time and tempera-
ture that they are used at, and the degree of manure contamination and the susceptibility of the agent to fecal deactivation. Until that information is available, producers should titrate the number of cow passes against the pen prevalence of reported infectious hoof disease to achieve least cost prevention. If the last pen of cows through the bath has a significantly greater prevalence of infection than the rest of the herd, then the number of cow passes between solution changes should be reduced.

A wide range of footbath dimensions was recorded in the surveyed herds. Notably, the length of the footbaths ranged from 1.6 to 4.6 m, width ranged from 0.3 to 3.5 m, and the volume of the baths varied almost 18 fold, ranging from 80 to 1417 L. Given the cost of the antibacterial agents used, there was a clear tendency to use smaller volume baths in the majority of herds, with the median volume of 189 L. However, short baths influence the number of steps taken through the bath and small volumes of bath solution may become rapidly contaminated with manure – both from defecation and from contaminated legs and feet.

Our observational study of cow behavior and use of water-filled footbaths of different dimensions demonstrates the impact on the number of immersions of the rear feet as the cows pass through the bath. The study design and analysis was compromised by an inability to accurately record individual animal identification, precluding the ability to account for individual cow variation from day to day and bath to bath. The camera angle required to observe the cows’ feet accurately did not allow for identification of the cows. The fact that the footbath dimensions once changed, could not be changed back, also failed to provide for a switch-back design, which would have strengthened the conclusions. The fact that this is merely an observational study is also an acknowledged weakness, with a general, as yet unproven, assumption that an increase in foot immersions per cow pass will enhance the overall efficacy of the footbath. This hypothesis requires further testing in a controlled prospective study, but early clinical impressions are promising. However, although limited, the data were consistent between observation days for the same bath dimensions, and it is not unreasonable to approach footbath design from the perspective that optimizing foot immersions for baths at a given volume would lead to equal or better efficacy of the antibacterial agent used.

In order to achieve at least two immersions per rear foot with a probability >95%, the footbath needs to be at least 3.0 m in length. A higher step-in height of 28 cm compared to 15 cm significantly increased the number of feet receiving more than one immersion, but the difference was small compared to the effect of increased length. Regardless, the higher step-in was tolerated well by the cows and it served to retain more solution at the end of bath use. A significantly greater number of foot immersions were observed in the 3.7 m bath compared to the 3.0 m bath, and this small increase in length may be worthwhile to receive the potential benefit of three or more foot immersions. The narrower bath dimensions were well tolerated to 0.5 m, with few cows stumbling. However, it was noticeable that passage through the bath for cows with the largest udders was easier at 0.6 m.

Conclusions

The design and management of footbaths for the prevention of infectious hoof disease varies widely between herds. While copper sulfate and formalin continue to be commonly used, there is a need for improved recommendations for footbath design and operation to maximize antibacterial effectiveness at least cost. In order to optimize foot immersions per cow pass, while limiting footbath volume to ~190–200 L, we recommend a single bath 3.0–3.7 m long, 0.5–0.6 m wide, with sloped side walls, with a step-in height of 28 cm (Fig. 3). This design will ensure that rear feet receive at least two immersions per cow pass with 95% probability.

Conflict of interest statement

N.B. Cook co-developed the First Step program with Zinpro and has spoken at meetings around the world on lameness prevention. None of the other authors has a financial or personal relationship with any people or organisations that could inappropriately influence or bias the content of the paper.

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