The Veterinary Journal 193 (2012) 669–673

Contents lists available at SciVerse ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

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

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ARTICLE INFO

Keywords:
Footbaths
Digital dermatitis
Dairy cows

ABSTRACT

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.

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

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http://dx.doi.org/10.1016/j.tvjl.2012.06.051

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. Holzhauer 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 world-wide. 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 over the course of the trial, with no new additions to the pen. A custom-designed footbath was set-up in a transfer lane to test the hypothesis that the design and dimensions of the bath influence the number of immersions the rear feet receive as the cows pass through the bath. The custom bath allowed for the testing of four different bath dimensions (1.8×0.76 m, 2.4×0.6 m, 3.0×0.5 m and 3.7×0.5 m), designed to achieve a final footbath volume of ~190–200 L.

The baths tested were made narrower with sloped wooden side-walls, to control final footbath volume. For the two shortest bath lengths, two different step-in heights (15 cm and 28 cm) were tested to determine the influence of a higher step on foot immersions. The design of the bath was such that the dimension changes increased from the shortest to the longest bath length. Once altered, the bath could not be changed back to the shorter dimension. On test day, the bath was filled to a depth of 10 cm with water. Cows were filmed with two DCRTRV900 MiniDV camcorders (Sony) located behind and in front of the bath, targeted at the cows' legs and feet. Each test observation was repeated on two consecutive days after 2 days where the cows were allowed to walk through the new bath and become 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 the frequency of foot immersions was examined using the GLIMMIX procedure of SAS, with cow limb as a random term, with both footbath length and step-in height included as fixed effects to determine the probability of cows receiving at least two immersions per rear foot. A proportional logistic (ordinal) model was created using the LOGISTIC procedure of SAS for foot immersion data confined to the 28 cm step-in height and the four different bath lengths (1.8, 2.4, 3.0 and 3.7 m) considering one, two, three and four or more foot immersions as the model outcome.

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 1
Summary of footbath design and management for 65 freestall housed dairy herds in five different countries (US, Japan, Spain, UK and New Zealand).

Parameter	Footbath dimensions			Volume of solution (L)	Frequency of use		Cow passes between solution changes
	Length (m)	Width (m)	Depth of fill (m)		Times per day	Days per week	
Median (range)	2.03 (1.57–4.55)	0.81 (0.30–3.51)	0.11 (0.05–0.18)	189 (80–1417)	1 (1–4)	3.0 (1–7)	250 (80–3000)
Mean (SD)	2.25 (0.61)	1.05 (0.56)	0.11 (0.03)	281 (252)	1.4 (0.7)	4.0 (1.9)	382 (427)