Effectiveness of Copper Sulfate for Footbath Solutions in Dairy Cattle

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Abstract: The aim of this study was to identify the loss of antiseptic effect of copper sulfate (CuSO4) if associated with the number of cow passing in footbath. A total of 360 Holstein and Simmental cows were milked three times daily in 2x12 herringbone milking parlor. After 360 cows passing from footbath (220x90x15 cm) containing 0%, 2% and 4% CuSO4, the sample was collected for pH and microbiology. The loss of antiseptic effectiveness was considered when pH more than 5. The mean pH at the end of 15 passages of cows was 8.13, 5.00, and 4.20 for 0%, 2% and 4% CuSO4 solutions. pH was greater than 5.0 after 7 passages of 24-cows in 2% CuSO4 concentration and did not exceed 5 even after 15 passages in 4% CuSO4 concentration. Change in color was correlated with pH. Samples were incubated for 24-72 hours for bacterial and fungal growth. *E.coli* was present at control group of CuSO4 concentrations, whereas fungus was not present. In conclusion, increasing pH due to the number of cow passing indicated the effectiveness of CuSO4 in footbath was lost. Antiseptic effect in 2% CuSO4 solution was lost after 168 cows passing through footbath, whereas antiseptic effect in 4% CuSO4 solution lost after 360 cows passing through footbath.

Keywords: Copper sulfate, Dairy cow, *Escherichia coli*, Footbath, pH.

Süt Sığırları Ayak Banyolarında Bakır Sülfat Solüsyonlarının Etkinliği

Öz: Bu çalışmanın amacı, bakır sülfatının (CuSO4) etkisinin ayak banyosunda geçen sığır sayısına bağlı olup olmadığını saptamaktır. Çalışmanın gerçekleştirilidği sağlamak maksatı içinde; Holştayn ve Simmental rüks 360 baş inek, 24'üncütemsinde 15 ayrı grup şeklinde günde üç defa sağlandırılır. Hayvanların tamamı, %0, %2 ve %4 CuSO4 içeren ayak banyosundan (220x90x15 cm) geçirildi. Antiseptik etkisi ayak banyosundan 24 hayvan geçtiğince, banyo sıvısından örnek alındı. Birlikte bu örnekler pH ve mikrobiyolojik değerlendirme için edildi. Antiseptik etkisi ile ilgili verileri analiz edildi. 360 hayvanın geçtiğinde pH >5 olan ayak banyosundaki kümasyaların antiseptik etkisi kaybettiği belirlendi. İçlerinden 360 hayvanın geçtiğinde geride kalan %0, %2 ve %4 bakır sülfat solüsyonlarının pH ortalaması sırasıyla 8.13, 5.00 ve 4.20 olarak bulundu. %2 ve %4 bakır sülfat solüsyonundan *E.coli* bulunurken, %0 bakır sülfat solüsyonunda *E.coli* bulunmamıştır. Sonuç olarak, pH değerinin ayak banyosunda %2 ve %4 bakır sülfat solüsyonunu etkilediği saptandı. %0 ve %2 bakır sülfat solüsyonunda 168 hayvan, %4 bakır sülfat solüsyonundan 360 hayvan geçtiğinden sonra antiseptik etkisi kaybettiği belirlendi.

Anahtar Kelimeler: Ayak banyosu, Bakır sülfat, *Escherichia coli*, pH, Süt sağır.
INTRODUCTION

Lameness and foot-related problems are major concern in the dairy industries because of their common occurrence and causes lost milk production (1,2,3). Cattle lameness is a leading cause of welfare and the productivity in dairy farming (4,5,6). Worldwide incidence is reported as high as 26% of all dairy cattle (7,8) with a much higher incidence in high producing dairies in temperate countries. The USA has an incidence 59% and use of footbaths to control hoof diseases because 22% of cows are being affected (9), an incidence of 35%, in Canada 62% in the UK whereas sole ulcers (40%), white line lesions (29%) and digital dermatitis as recognized as the most common lesions on dairy farms in the UK (10) and a staggering 69% in Turkey (1,11).

There are several areas on the farm that can lead to cattle lameness include nutrition (12), feeding management, animal behavior, stress, cow comfort, and infrequent hoof trimming (11). Lesions that cause lameness in dairy cows causes stress, produce severe pain, reduces productivity and are a major animal welfare issue (13,14). According to Cook (12), footbaths are used as a prevention management tool, not a method of treatment for hoof lesions.

Prevention of lameness and other hygiene-related lameness can be avoided with good foot hygiene and footbath management regularly (10,12,15). Footbath treatment programs are used on most dairies as one of the best and most effective means of controlling hoof disease. Use of a footbath in the dairy industry for the control of infectious hoof disease is wide-spread in North America and elsewhere around the world (9,12). Most cattle mobility experts recognise the value of regular footbathing on the dairy farm; preferably on a daily basis or each time the cows are moved to or from the milking area (10,12).

Laven and Logue (7) concluded that there was a lack of scientific evidence regarding the treatment and control diseases with foot baths such that firm recommendations on what products and concentrations to use cannot be made. Many research reports with multiple foot bathing regimens studies is difficult because each study calculates statistical significance in comparison to other treatment groups within the experiment, and not all used untreated or placebo treated control groups for comparison. Later on, empirical advice for changing footbath solutions every 100 to 300 cows (4,9,10,16) appears to be followed by most farms, but it is challenged on larger dairies and there is very little in the scientific literature to help producers with their decision making (12).

Copper sulfate appears to be the most effective antibacterial agent (5,17,18). Where copper sulfate can be used, it is clearly the first choice antibacterial to be considered (17). Based on research report, copper sulfate footbaths in concentrations 5% and above have been shown to reduce new digital dermatitis lesions compared to untreated controls whilst in concentration 2% and above have been shown to be equivalent in preventing new infections in cows that are already unaffected (2).

A quick search indicates great concern about potential soil toxicity from footbaths using copper sulfate (11). Concentration of copper sulfate should not be higher than 5% as long as pH is not less than 3.0. Copper sulfate appears the most efficacious agent to include in all a footbath program, but disposal concerns should limit the frequency of its use (10,12). Despite an extensive literature search, no reports were found regarding the cow passing number through the footbath in different concentration of CuSO4. Previous study only reported 5%-10% CuSO4 solution allows a median of 200 cows in the herd's (9,10,12,16). The current industry rule of thumb is 200 to 300 cow passes before footbaths need to be changed. For producers looking to use less copper sulfate and save money, using less copper sulfate also means less to purchase (9,12).

Therefore, the aim of the present study was to determine the effectiveness of copper sulfate in less concentration to know the maximum number of cow passing through the footbath solution, advice for
Effectiveness of Copper Sulfate Footbath Solution

Prastiwi et al.

Effectiveness of Copper Sulfate Footbath Solution

It is recommended to run a footbath twice a week or more and to refresh solution after every 200 cow passes (4,9). This number is somewhat variable and should be optimized for each farm, taking into account herd size, contamination with organic material and temperatures. The averages below suggest that most dairies in the study are meeting those minimums.

MATERIALS and METHODS

This study was approved by the Ataturk University Faculty of Veterinary Medicine Clinical Research Ethics Committee (AUVEAK) No: 2015/5.

Footbath

Footbath used in dairy herds to maintain and control optimum hoof health (9). Foot bathing is considered an essential procedure and should be undertaken on a regular basis (12). The dimensions of footbath were selected approached the recommendation from Cook et al. (9,12) and Shearer and Van Amstel (19); each bath was 2.2 m long, 0.90 wide, and held a fluid depth of 0.15 m, for a combined volume of 225 L. Farm used copper sulfate (CuSO₄), as it is the most common chemical used in footbaths in Turkey (4,5). The concentration of CuSO₄ solutions were 2% and 4%. Data on the Dutpinar farm (360 cows) were collected 3 times a day within 9 days between May and September 2015 by 1 trained observers and the first author.

Clean copper-based footbath solution should be blue-green in color, not brown (5,10,12). Farm used digital pH-meter to check the pH of footbath. An initial footbath should have a pH between 3.5 and 4.5 for optimal results. If pH is above 5.0, the footbath is no longer effective and must be changed (20). The current industry rule of thumb is 200 to 300 cow passes before footbaths need to be changed. This study was to calculate the average number of cow passes per bath by monitoring pH values and color changed. Depending on organic load and environmental conditions, efficiently run footbaths can increase the number of cow passes.

Refeshing and Refilling of Footbath Solution

Data were entered into Microsoft Access (Microsoft Corp., Redmond, WA), and statistical analyses were analyzed by one-way ANOVA with repeated measures option. For all analyses, a P-value <0.05 was considered significant.

RESULTS

Farms and Footbath Practices

Footbath design and footbathing practices before footbath intervention had a median length of 220 cm (range, 183 to 370) and a mean depth of 15 cm (range, 10 to 21). Prewashing cows’ feet consist of normal water placed at the exit line after milking process. On average, footbath contents were changing footbath solutions and reduce soil toxicity. It also was to compare of efficacy a 2% and 4% CuSO₄ copper sulfate footbath solution with negative control in dairy cattle. The use and management of the footbath are critical to the success of the program.

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replaced every total of 360 cow passes without identify the loss of antiseptic effect of copper sulfate (CuSO₄) in footbath. The farm (n = 1) used a chemical (mostly with copper sulfate), and chemical concentration was less than 5% in order to reduce the cost and reduce soil toxicity. Within-herd prevalence of lameness cases was considered low (<10%).

The Color Change

The color of initial sample was light blue, 2nd sample to 13th sample were changed from light became dark green (Figure 1). Then, color changed up to dark brown until 15th group’s sample. Color changed caused by exposure of manure, slurry, and urine in the footbath. Color changed had correlation in increasing pH and decrease the effectiveness of the CuSO₄ solutions. Color change as well as increased pH range indicated footbath solution needs to be recharged.

![Figure 1. Color changing of 15 pH samples from footbath.](image)

**Figure 1.** Color changing of 15 pH samples from footbath.

**Şekil 1.** Ayak banyosundaki 15 pH örneklerinin renk değişimi.

Bacterial Finding

Microbiological examination result performed *Escherichia coli* as an indicator of footbath contamination only found at control group. *Escherichia coli* was only found at control group (0% CuSO₄ concentrations), whereas fungus was not present. *Escherichia coli* (abbreviated as *E. coli*) is a type of bacteria that normally found in the environment, foods, and intestines of people and animals (15). In that regard, on farm only apparent lameness in low prevalence during intervention.

**pH Changing**

The mean of initial pH was 7.322, 4.507, 3.643. Mean pH of 7th group were increased to 8.265, 5.000, 4.275. Mean pH of 15th group were 8.240, 5.198, 4.357 for 0%, 2% and 4% CuSO₄ solutions (Figure 2). Footbath solution should be maintained at 3.5-5.5 pH (10, 12). pH was greater than 5.0 after 7 passages of 24-cows when CuSO₄ concentration was 2%. Increasing pH indicated the effectiveness of CuSO₄ was lost and footbath concentration should be changed. pH average at 4% CuSO₄ concentration was did not exceed 5 even after 15 passages of 24-cows. It showed that 4% CuSO₄ concentration could be applied in big herds.

![Figure 2. Correlation between cow passes and pH average.](image)

**Figure 2.** Correlation between cow passes and pH average.

**Şekil 2.** İnek geçişleri ile pH ortalaması arasındaki korelasyon.

**Number of Cow Passes**

We concluded that on farm with 2% CuSO₄ solution should be changed after 168 cows passed through the footbath. 2% CuSO₄ solution only recommended in small herd. 4% CuSO₄ solution can be changed after 360 cows have passed though the
Effectiveness of Copper Sulfate Footbath. It is suggested to use 4% CuSO$_4$ concentration in big herds (range 360 to 400 cows). Proper footbath use will make hoof diseases management more effective and save money by reducing the amount of solution used. Ideally, in the future, there would be a bath side test to tell when the solution needs to be changed. The solution can then be directly pumped into the bath. Several

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**Statistical Analysis**

There is statistically significant differences (Table 1) in the number of cow passing with group of cows ($P=.000$).

**Table 1.** Statistical analysis with pH rate variable.

| Variance source | Type III squares sum | SD | Average squares | F | P     |
|-----------------|----------------------|----|----------------|---|-------|
| Corrected model | 766.379               | 47 | 16.306         | 224.767 | .000  |
| Intersection    | 8876.003              | 1  | 8876.003       | 122350.122 | .000  |
| Group           | 735.992               | 2  | 367.996        | 5072.596 | .000  |
| Transition      | 11.867                | 15 | .791           | 10.905 | .000  |
| Group*Transition| .871                 | 30 | .029           | .400 | .000  |
| Error           | 16.395                | 226| .073           | .998 |       |
| Total corrected | 9481.355              | 274|                |       |       |
| Total           | 782.774               | 273|                |       |       |

**DISCUSSION and CONCLUSION**

Question remains regarding the best footbath solution, its concentration and number of passing cows through the footbath. Copper sulfate (CuSO$_4$), as it is the most common chemical used in footbaths in Turkey, Canada, USA and other countries (2,6,18), most research on footbathing protocols has been conducted on experimental dairy farms (17) with limited sample sizes or with relatively short follow-up periods (18).

In this study, *E.coli* was only present at control group of copper sulfate concentrations, whereas fungus was not present. Predictably, degree of pH, bath volume, and perhaps water quality influence the duration of activity. The loss of antiseptic effectiveness was considered when pH exceeds 5 (20).

One of the reasons footbaths lose their effectiveness and need to be changed is that manure accumulation in the footbath causes the pH to rise. The copper becomes bound and is unable to serve in its antibacterial role (8,15). Concentration of copper sulfate should not be higher than 5% in order to reduce soil toxicity (5,11). Fortunately, producers have options to reduce copper sulfate use, including pH adjusters that can safely lower the pH of footbath water to better ionize the copper. More ionized copper allows for more available copper in footbath, and that means a more efficient footbath that requires less copper sulfate on the farm and in the environment (9,12).

However, the empirical recommendation around 150-200 cow passes (4,12) appears to have merit and in large herds matches typical pen sizes, so that solutions can be changed between pens as they are milked. Such an approach is somewhat time consuming and intensive, but between herds under a variety of different circumstances, solution changes have been recommended typically after 100 to 300 cow passes (10,12,16).

Based on this study showed that pH of 4% CuSO$_4$ were not reach 5.0 and allowing 360 cow passes through footbath. Several control strategies have been recommended, including maintaining a clean, dry environment, individual topical treatment of affected cows, and herd-level strategies, including
Footbathing (12). Footbaths are a common preventative approach due to the labor involved in treating large numbers of affected cows, along with strong evidence from intervention trials supporting footbath efficacy in reducing Digital Dermatitis (DD) prevalence compared with negative controls (4,11,14). However, there is a wide variation in on-farm practices related to footbath management (4,9,10,12). Administration of parenteral antibiotics in combination with footbath was also highly effective to treat the acute foot diseases (21).

Proper use and management by maintaining of pH value can improve efficacy of footbaths (10,12,20). These findings suggest a gap between evidence-based management practices and on-farm implementation of footbaths. Most studies have compared chemicals and concentrations used in footbaths, but there is a paucity of research focused on number of cow passing of CuSO₄ under 5% footbath practices for hoof prevention (8,12). One study assessed effects of various footbath dimensions on number of foot immersions and recommended long (3 m) and deep (0.28 cm) footbaths to optimize chemical delivery to cows’ feet (4,9,12). However, in that study, the number of cow passes of various footbath concentration were not reported.

It should be noted that there is limited research on when is the optimal time to change footbath solutions. Currently, it is not known if the optimal interval for changing footbath solutions is dependent upon time (4,10), pH changing and number of cow passes. In addition, the optimal interval for changing footbath solutions may vary from dairy to dairy depending upon cleanliness of cows, footbath size and footbath solution (10,12,20). Developing and control of pH changing of footbath may allow some producers to reduce the frequency of changing footbath solutions, while effectively controlling lameness and hoof lesions.

It is recommended that footbath solutions be changed every 360 cows in a 4% CuSO₄ footbath solution where the pH was no exceed than 5. If group sizes less than 300 cows, if producers used less concentration of CuSO₄ (2%), they should alter times to replace the footbath solutions in every 168 cows, so that cows in each group have access to fresh solution periodically. 4% CuSO₄ solution are active for around 360 cow passes, while 2% CuSO₄ solution may last only 168 passes. Activity will also depend on the amount of manure contamination.

As a result using less copper sulfate to around 2 to 4 percent instead of 5 to 10 percent to reduce soil toxicity and still have effectiveness prevent lameness and hoof-related lesions. Finally, more research needs to be conducted to determine efficacy of commercially available footbath products. In addition, a quick test needs to be developed to allow the producer to determine when the footbath solution is no longer effective in preventing and controlling hoof lesions. Implementation of a proper footbath design and improvement of footbath management through standardization of a protocol based on scientific literature decreased prevalence hoof lesions and lameness. The footbath design entailed a CuSO₄ footbath solution that measured 2.2 m long, 0.90 m wide, 0.15 m high, with three times a week footbath protocol using 2% and 4% CuSO₄ for 3 consecutive milkings, replaced at a maximum of 168 cow passes for 2% CuSO₄ and 360 cows for 4% CuSO₄. pH greater than 5 indicated the antiseptic effect has been lost. 2% CuSO₄ solution should be changed after 168 cows passed through the footbath and recommended in small herd. It is suggested to us 4% CuSO₄ in order to maintain mean pH, antiseptic effect, absence of microbial agent and footbath volume that decrease during passage for allowing 360 cows in big herds. Therefore, we concluded that following science-based recommendations on footbathing practices was effective on less copper sulfate concentration. In addition, improving cow cleanliness would further result in prevent of hoof diseases.
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Conflict of interest

The authors declare that they have no conflict of interest.

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