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Effectiveness of Copper Sulfate for Footbath Solutions in Dairy Cattle

Artina PRASTIWI[1a]✉, Zafer OKUMUŞ[1b], Armağan HAYIRLI[2c], Demet ÇELEBİ[3d], Latif Emrah YANMAZ[1e], Elif DOĞAN[4f], Mümin Gökhan ŞENOCAK[1g], Uğur ERSOZ[1h]

1. Atatürk University, Faculty of Veterinary Medicine, Department of Veterinary Surgery, Erzurum, TURKEY.
2. Atatürk University, Faculty of Veterinary Medicine, Department of Animal Nutrition and Nutritional Disorders, Erzurum, TURKEY.
3. Atatürk University, Faculty of Veterinary Medicine, Department of Microbiology, Erzurum, TURKEY.
4. Kastamonu University, Faculty of Veterinary Medicine, Department of Veterinary Surgery, Kastamonu, TURKEY.
ORCID: 0000-0002-5886-5459[a], 0000-0002-7525-9725[b], 0000-0002-4446-0848[c], 0000-0002-2355-0561[d], 0000-0001-5890-8271[e], 0000-0002-3321-8116[f], 0000-0002-8855-8847[g], 0000-0002-1687-2327[h]

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Abstract: The aim of this study was to identify the loss of antiseptic effect of copper sulfate ($CuSO_4$) 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% $CuSO_4$, 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% $CuSO_4$ solutions. pH was greater than 5.0 after 7 passages of 24-cows in 2% $CuSO_4$ concentration and did not exceed 5 even after 15 passages in 4% $CuSO_4$ 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 $CuSO_4$ concentrations, whereas fungus was not present. In conclusion, increasing pH due to the number of cow passing indicated the effectiveness of $CuSO_4$ in footbath was lost. Antiseptic effect in 2% $CuSO_4$ solution was lost after 168 cows passing through footbath, whereas antiseptic effect in 4% $CuSO_4$ 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 ($CuSO_4$) etkisinin ayak banyosunda geçen sığır sayısına bağlı olup olmadığını saptamaktır. Çalışmanın gerçekleştirildiği sağmal işletmede; Holştayn ve Simmental ırkı 360 baş inek, 24'lü sağım ünitesinde 15 ayrı grup şeklinde günde üç defa sağıldılar. Hayvanların tamamı, %0, %2 ve %4 $CuSO_4$ içeren ayak banyosundan (220x90x15cm) geçirildi. Antiseptik ayak banyosundan 24 hayvan geçtikçe, banyo sıvısından örnek alındı. Biriktirilen örnekler pH ve mikrobiyolojik yönden incelendi. pH>5 olan ayak banyolarındaki kimyasalların antiseptik özelliğini kaybettiği belirlendi. İçlerinden 360 hayvan geçtikten sonra geride kalan %0, %2 ve %4 bakır sülfat solüsyonlarının pH ortalaması sırasıyla 8.13, 5.00 ve 4.20 olarak bulundu. %2 $CuSO_4$ solüsyonundan 7.gruptaki hayvanlar geçtikten sonra ortalama pH değeri 5'den yüksek bulunurken, %4'lük $CuSO_4$ solüsyonundan 15.gruptaki hayvanlar geçtikten sonra ortalama pH değeri 5'ten düşük olduğu saptandı. Ayak banyosunun renginin pH değişimi ile ilgili olduğu belirlendi. Örnekler bakteri ve mantar gelişimi için 24-72 saat inkübe edildi. Kontrol grup $CuSO_4$ solüsyonlarında *E.coli* bulunurken, yapılan mantar incelemesinde hiç bir grupta herhangi bir üremeye rastlanmadı. Sonuç olarak; pH değerinin ayak banyosundan kaç hayvan geçtiği ile ilişkili olduğu saptandı. %2'lik $CuSO_4$ konsantrasyonundan 168 hayvan, %4'lük konsantrasyonundan 360 hayvan geçtikten sonra antiseptik etkinliğini kaybettiği belirlendi.

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

✉ Artina Prastiwi
Atatürk University, Faculty of Veterinary Medicine, Department of Veterinary Surgery, Erzurum, TURKEY.
e-mail: prastiwiartina@gmail.com

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 $CuSO_4$. Previous study only reported 5%-10% $CuSO_4$ solution allows a median of 200 cows in the herds (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

changing footbath solutions and reduce soil toxicity. It also was to compare of efficacy a 2% and 4% $CuSO_4$ 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.

MATERIALS and METHODS

This study was approved by the Ataturk University Faculty of Veterinary Medicine Clinical Research Ethics Committee (AÜVFEAK) 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 ($CuSO_4$), as it is the most common chemical used in footbaths in Turkey (4,5). The concentration of $CuSO_4$ solutions were 2% and 4%. Data on the Dutpınar 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.

Refreshing and Refilling of 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.

Study Design

The experiment was conducted to test the effectiveness of different concentration footbathing using 2% and 4% $CuSO_4$ in group of daily cows. Before intervention, no changes were made to the farms' original footbath. Three hundred sixty Holstein and Simmental cows divided into 15 groups, each group consisted of 24 cows and were milked three times daily in 2x12 herringbone milking parlor. During the study, cows walked through allocated footbath solutions after milking on 3 times a day. Samples for pH and microbiological examination were taken after cows passing 0%, 2% and 4% $CuSO_4$ solutions. The color change and pH more than 5 indicated that antiseptic effect was loss. Data were analyzed by one-way ANOVA with repeated measures option.

Statistical Analyses

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

replaced every total of 360 cow passes without identify the loss of antiseptic effect of copper sulfate ($CuSO_4$) 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 13rd 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 $CuSO_4$ solutions. Color change as well as increased pH range indicated footbath solution needs to be recharged.

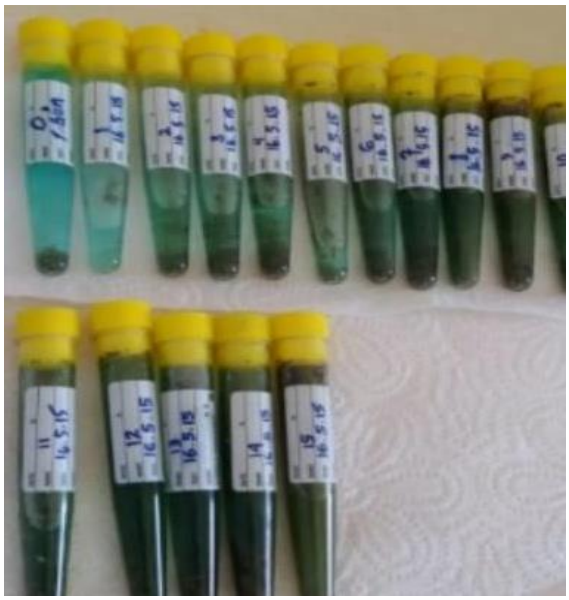

Figure 1. Color changing of 15 pH samples from footbath.
Şekil 1. Ayak banyosundaki 15 pH örneklerinin renk değişimi.

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% $CuSO_4$ 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% $CuSO_4$ 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 $CuSO_4$ concentration was 2%. Increasing pH indicated the effectiveness of $CuSO_4$ was lost and footbath concentration should be changed. pH average at 4% $CuSO_4$ concentration was did not exceed 5 even after 15 passages of 24-cows. It showed that 4% $CuSO_4$ concentration could be applied in big herds.

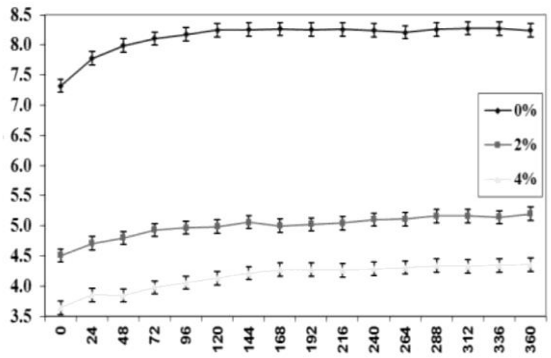

Figure 2. Correlation between cow passes and pH average.
Şekil 2. İnek geçişleri ile pH ortalaması arasındaki korelasyon.

Number of Cow Passes

We concluded that on farm with 2% $CuSO_4$ solution should be changed after 168 cows passed through the footbath. 2% $CuSO_4$ solution only recommended in small herd. 4% $CuSO_4$ solution can be changed after 360 cows have passed though the

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 milking machine manufactures have already invested in automated equipment to facilitate footbath mixing in large herds.

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.
Tablo 1. pH oranı değişkenli istatistiksel analiz sonuçları.

Variance source	Type III squares sum	SD	Average squares	F	P
Corrected model	766.379[a]	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			

Dependent variable = pH level; a. R Squared = .979 (R Squared corrected = .975)

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 $CuSO_4$ 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% $CuSO_4$ footbath solution where the pH was no exceed than 5. If group sizes less than 300 cows, if producers used less concentration of $CuSO_4$ (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% $CuSO_4$ solution are active for around 360 cow passes, while 2% $CuSO_4$ 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 $CuSO_4$ 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% $CuSO_4$ for 3 consecutive milkings, replaced at a maximum of 168 cow passes for 2% $CuSO_4$ and 360 cows for 4% $CuSO_4$. pH greater than 5 indicated the antiseptic effect has been lost. 2% $CuSO_4$ solution should be changed after 168 cows passed through the footbath and recommended in small herd. It is suggested to us 4% $CuSO_4$ 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.

REFERENCES

1. Atasoy N., 2003. Erzurum yöresinde süt sığırlarında görülen ayak hastalıkları insidansı ve bunların sağaltımı. YYÜ Vet Fak Derg, 14, 1, 1-5.
2. Solano L., Barkema HW., Jacobs C., Orsel K., 2017. Validation of the M-stage scoring system for digital dermatitis on dairy cows in the milking parlor. Dairy Sci, 100, 1592-1603.
3. Relun A., Lehebel A., Chesnin A., Guatteo R., Bareille N., 2013. Association between digital dermatitis lesions and test-day milk yield of Holstein cows from 41 French dairy farms. Dairy Sci, 96, 2190-2200.
4. Fjeldaas T., Knappe-Poindecker M., Boe KE., Larssen RB., 2014. Water footbath, automatic flushing, and disinfection to improve the health of bovine feet. Dairy Sci, 97, 2835-2846.
5. Kamiloğlu A., 2014. Çiftlik hayvanlarında ayak hastalıkları. 1.baskı., 60-133, Medipres, Ankara.
6. Solano L., Barkema HW., Pajor EA., Mason S., LeBlanc SJ., Zaffino Heyerhoff JC., Nash CGR., Haley DB., Vasseur E., Pellerin D., Rushen J., de Passille AM., Orsel K., 2015. Prevalence of lameness and associated risk factors in Canadian Holstein-Friesian cows housed in freestall barns. Dairy Sci, 98, 6978-6991.
7. Laven RA., Hunt H., 2002. Evaluation of copper sulfate, formalin and peracetic acid in footbaths for the treatment of digital dermatitis in cattle. Vet Rec, 151, 141.
8. Potterton SL., Bell NJ., Whay HR., Berry EA., Atkinson OC., Dean RS., Main RJ., Huxley JN., 2012. A descriptive review of the peer and non-peer reviewed literature on the treatment and prevention of foot lameness in cattle published between 2000 and 2001. Vet, 193, 612-616.
9. Bill E., Lowell M., 2007. Copper sulphate for footbaths – issues and alternatives. Proceedings on the Tri-State Dairy Nutrition Conference, Ohio State University.
10. Logue DN., Gibert T., Parkin T., Thomson S., Taylor DJ., 2012. A field evaluation of a footbathing solution for the control of digital dermatitis in cattle. Vet, 193, 664-668.
11. Evans NJ., Murray RD., Carter SD., 2016. Bovine digital dermatitis: current concepts from laboratory to farm. Vet, 211, 3-13.
12. Cook NB., Rieman J., Gomez A., Burgi K., 2012. Observations on the design and use of footbaths for the control of infectious hoof disease in dairy cattle. Vet, 193, 669-673.
13. Krull AC., Cooper VL., Coatney JW., Shearer JK., Gorden PJ., Plummer PJ., 2016. A highly effective protocol for the rapid and consistent induction of digital dermatitis in Holstein calves. PLoS One., 11, e0154481.
14. Palmer M., O'Connell N., 2015. Digital dermatitis in dairy cows: A review of risk factors and potential sources of between-animal variation in susceptibility. Animals (Basel), 5, 512-535.
15. Nielsen MW., Strube ML., Isbrand A., Al-Medrasi WDHM., Boye M., Jensen TK., 2016. Potential bacterial core species associated with digital dermatitis in cattle herds identified by molecular profiling of interdigital skin samples. Vet Microbiol, 186, 139-149.
16. Rankin M., 2004. Agronomic and environmental issues with foot bath solution land spreading. Proceedings on the Four-State Dairy Nutrition and Management Conference, Dubuque, Iowa.
17. Speijers MH., Finney GA., Mcbride J., Watson S., Logue DN., O'Connell NE., 2012. Effectiveness of different footbathing frequencies using copper sulfate in the control of digital dermatitis in dairy

cows. Dairy Sci, 95, 2955-2964.

18. Teixeira AG., Machado VS., Caixeta LS., Pereira RV., Bicalho RC., 2010. Efficacy of formalin, copper sulfate, and a commercial footbath product in the control of digital dermatitis. Dairy Sci, 93, 3628-3634.
19. Solano L., Barkema HW., Mason S., Pajor EA., LeBlanc SJ., Orsel K., 2016. Prevalence and distribution of foot lesions in dairy cattle in Alberta, Canada. Dairy Sci, 99, 6828-6841.
20. Cook NB., 2017. A review of the design and management of footbaths for dairy cattle. Vet Clin North Am: Food Anim Practice, 33, 195-225.
21. Yurdakul İ., Özdemir S., 2012. Sığır ayak hastalıklarında antibiyotiklerin kullanımı. Atatürk Üniversitesi Vet Bil Derg, 7, 147-153.