http://dx.doi.org/10.1590/1678-4162-12578

Arq. Bras. Med. Vet. Zootec., v.74, n.3, p.383-389, 2022

Physical and chemical aspects of the footbath from dairy farms with different production systems in Arapoti, Paraná

[*Aspectos físicos e químicos do pedilúvio de propriedades leiteiras com diferentes sistemas de produção, no município de Arapoti, Paraná*]

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ABSTRACT

This study aimed to evaluate copper sulfate solutions at 5% and 10% concentrations in footbaths from three dairy farms (A, B and C) with free stall and compost barn production systems, located in the municipality of Arapoti, Parana, Brazil. Farms A, B and C were composed of 537, 88 and 208 lactating cows, respectively, all conditioned to the use of a footbath. Every seven days, before and after the passage of each batch of cows through the footbath, samples of the solution were collected for the evaluation of pH, temperature, and the volume of the solution measured. Farms A and C had higher pH alkalinization due to the greater number of batch passages, from the third batch onwards, and also a reduction in the volume of the solution. It is concluded that the volume varied both with the number of animals that passed through the footbath and with the deposition of organic matter in the solution. The concentration of 10% copper sulfate solution was not able to inhibit pH changes. Furthermore, there was no standardization in the dimensions of the footbaths on the farms.

Keywords**:** cooper sulfate, cows, claw, pH

RESUMO

Objetivou-se avaliar as soluções de sulfato de cobre nas concentrações de 5% e 10%, em pedilúvios de três propriedades leiteiras (A, B e C), com sistemas de produção "free stall" e "compost barn", localizadas no município de Arapoti, Paraná, Brasil. As propriedades A, B e C eram compostas por 537, 88 e 208 vacas em lactação, respectivamente, todas condicionadas ao uso do pedilúvio. A cada sete dias, antes e após a passagem de cada lote de vacas pelo pedilúvio, foram colhidas amostras da solução para a avaliação do pH, da temperatura e do volume. As propriedades A e C tiveram alcalinização maior do pH devido ao maior número de passagem de lotes, a partir do terceiro lote, com redução também do volume da solução. Conclui-se que o volume variou tanto com o número de animais que passaram pelo pedilúvio quanto com a deposição de matéria orgânica na solução. A concentração da solução de sulfato de cobre a 10% não foi capaz de inibir as alterações de pH. Além disso, não houve padronização das dimensões dos pedilúvios nas fazendas.

Palavras-chave: sulfato de cobre, vacas, cascos, pH

INTRODUCTION

One of the most relevant problems of the locomotor system of cattle are the hoof diseases, which result in marked lameness and difficulty of locomotion due to pain, resulting in losses of up to 20% in milk production (Palmer and O'Connell, 2015; Krull *et al.* 2016), and are often underestimated due to the subclinical character (Alvergnas *et al*., 2019).

The foot bath is a method of prevention of infectious hoof disorders (Solano *et al*., 2017;

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Submitted: October 13, 2021. Accepted: April 2, 2022.

Alvergnas *et al*., 2019). The use of copper sulfate ($CuSO_4$) in the footbaths has positive results and is widely used in dairy farms, however, there are recommendations regarding the design and management of the footbath, to improve antimicrobial efficacy and operational cost (Cook *et al*., 2012), and different concentrations are used, such as 2% and 4% (Prastiwi *et al*. 2019), and 5% (Speijers *et al*., 2012; Jacobs *et al*., 2019).

For this management to be effective, the solution in the footbath must cover the entire digit and the concentration of organic matter must be monitored, considering the number of animals passing through the solution (Jacobs *et al*., 2019). The footbath should contain the appropriate measurements to ensure that the posterior digits receive at least two immersions effectively (Cook *et al*., 2012; Cook, 2017).

The literature is still scarce in relation to the ideal number of animals that can pass through the prepared solution and when the solution should be changed (Rankin, 2004; Logue *et al*., 2012; Fjeldaas, *et al*., 2014), mainly due to the amount of organic matter deposited by the animals that can change the pH and temperature (Ariza, *et al*., 2017).

The objective of this work was to measure the pH, temperature, and volume of copper sulfate solution at 5% and 10% before and after the passage of animals through the foot baths of different dairy farms.

MATERIAL AND METHODS

This study was approved by the Ethics Committee on the Use of Animals of the University (05/2019). The study was carried out in three dairy farms, named "A", "B", and "C", composed of black and white Holstein cows of high dairy production located in the city of Arapoti (24°09'28"S 49°49'37"O), state of Paraná. The rainy season (January and February) is humid and cloudy, with a minimum temperature of 19.5°C and a maximum of 29°C, and rainfall index with a variation from 130mm to 210mm.

Farm "A" has average production of 16.000 liters/day with 537 lactating animals, divided into seven lots (Table 1). Three lots remained in a compost barn housing system and four lots remained in a free-stall housing system.

Table 1. Number of animals per lot and number of measures performed every seven days during four weeks in farm A

Measure	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
1	48	110	60	120	100	90	9
2	48	110	60	120	100	90	9
3	48	108	60	120	100	90	9
4	49	110	60	120	100	90	7

After milking, twice a week, the lactating cows walked down a corridor with concrete floors to the footbath, common to the two systems and then each lot returned to their accommodation. The foot bath composed of a copper sulfate solution ($CuSO_4$) at 10%, measured 3.45 meters long by 70 centimeters wide, 15 centimeters high and total volume of 362.25 liters, with one access step and another output and allowed at least two dives of the thoracic and pelvic limbs. The footbath box was sanitized with water every time before and after use.

Farm "B" has an average production of 3.600 liters of milk/day, with 88 lactating animals, divided into three lots that remained in a compost barn housing system. The lots were divided as follows: lot 1 composed of 35 animals, lot 2 with 40 animals and lot 3 with 13 animals. The analyses were performed once a week for four weeks. Every day, after the afternoon milking, the animals walked down a concrete corridor, passed through the footbath, and went to milking and at the end returned to the lodge. The footbath measured 1.75 meters long by 85 centimeters wide, 15 centimeters high and total volume of 223 liters, with one access step and another of exit and allowed at least two dives of the thoracic and pelvic limbs. The footbath was composed of a 4 to 5% $CuSO_4$ solution.

Table 2. Number of animals per lot and number of measures performed every seven days during four weeks in farm B

Measure	Lot 1	Lot 2	Lot 3
1	35	40	13
2	35	40	13
3	35	40	13
4	35	40	13

Farm "C" has an average production of 5,000 liters of milk/day, with 208 lactating cows, divided into three lots (Table 3) that remained in free-stall accommodation. Twice a week, after afternoon milking, the animals passed through the foot washer system, located at the entrance of the footbath, whose dimensions were 3.20 meters long, 85 centimeters wide, 5.6 centimeters high and only water was used as a solution. Then, they passed through a footbath of 3.20 meters long, 85 centimeters wide and 10 centimeters high, with a total volume of 272 liters and with access step and another of exit, allowing at least two dives of the thoracic and pelvic limbs. The solution used in the footbath was composed of $CuSO_4$ solution to 5%. In all farms, after the use of the footbath the solution was drained through a drain and deposited in a containment box.

Table 3. Number of animals per lot and number of measures performed every seven days during four weeks in farm C

Measure	Lot 1	Lot 2	Lot 3
1	24	110	74
2	21	104	72
3	20	103	71
4	20	100	70

In the footbath of each farm, the pH, volume, and temperature of the solution were measured. The initial volume was measured at each farm and measured with the aid of a ruler, temperature and pH using the digital pHmeter (KASVI®, Pinhais, PR, Brazil). These measurements were determined once a week for four weeks, within the box of each footbath before and after the passage of the lots. To verify the values of temperature and pH measured within the footbath, a sample was taken by fully submerging a 50mL collector cup, in triplicate samples into the center of the bath. When the bottom of the pot touched the bottom of the footbath it was tilted slightly towards the front of the race (so that the entire opening was immersed in the solution) and then raised up, according to Manning *et al*. (2017).

To compare the values of temperature, volume, and pH of the footbath solution at the entry and output of the lots, we applied the Student's T test for paired data to compare the entry and output of the first lot, and the independent Student's T method to compare the lots entry and outputs of each batch, considering the probability level of 5%.

RESULTS

For the measurements of pH, temperature and volume, the entry of lot 1 of each farm was used as a reference to compare with the output of this same lot and with the others, as shown in tables 4, 5 and 6.

Table 4. The pH, temperature, and volume of the $CuSO_4$ solution of the footbath in farm "A", comparing the entry of the animals from the first lot with the output of the same lot and the others after passing through the footbath

	pH	Temperature (ºC)	Volume (liters)
Entry Lot 1	3.60[a]±0.16	22.76[a] ±1.60	250.00[a]±0.00
Output Lot 1	3.98[a]±0.28	22.40 [a] ±1.03	246.00[a]±5.56
Output Lot 2	4.38[b]±0.17	22.43[a]±1.86	240.00[a]±2.99
Output Lot 3	4.63[b]±0.13	23.00[a]±1.54	230.00[a]±8.97
Output Lot 4	4.80[b]±0.20	22.95[a]±1.49	216.00[b]±2.82
Output Lot 5	4.83[b]±0.19	23.15[a]±1.89	212.00[b]±4.02
Output Lot 6	4.78[b]±0.29	23.22[a]±1.81	206.00[b]±12.86
Output Lot 7	4.88[b]±0.15	23.27[a]±1.97	204.00[b]±12.29

Means followed by different letters in the same column differ (P≤0.05) by the paired Student's T method performed to compare the entry and output of the first lot, and by the independent Student's T method to compare the lots entry and outputs of each batch.

Table 5. The pH, temperature, and volume in liters of the $CuSO_4$ solution of the footbath in the farm "B", comparing the entry of the animals from the first lot with the output of the same lot and the others after passing through the footbath

	pH	Temperature (ºC)	Volume (liters)
Entry Lot 1	3.55[a]±0.11	31.86[a]±1.74	250.00[a]±0.00
Output Lot 1	4.03[b]±0.24	31.11[a]±2.54	241.00[a]±5.83
Output Lot 2	4.34[b]±0.32	29.59[a]±2.53	233.00[a]±9.77
Output Lot 3	4.47[b]±0.31	28.10[b]±1.93	220.00[a]±14.26

Means followed by different letters in the same column differ (P≤0.05) by the paired Student's T method performed to compare the entry and output of the first lot, and by the independent Student's T method to compare the lots entry and outputs of each batch.

Table 6. The pH, temperature, and volume in liters of the $CuSO_4$ solution of the footbath in the farm "C", comparing the entry of the animals from the first lot with the output of the same lot and the others after passing through the footbath

	pH	Temperature (ºC)	Volume (liters)
Entry Lot 1	3.50[a]±0.41	25.77[a]±2.51	100.00[a]±0.00
Output Lot 1	3.95[b]±0.62	26.72[a]±2.60	106.00[a.]±4.03
Output Lot 2	4.40[b]±0.54	29.52[a]±3.74	111.00[b]±3.32
Output Lot 3	4.62[b]±0.49	28.22[a]±3.37	117.00[b]± 6.24

Means followed by different letters in the same column differ (P≤0.05) by the paired Student's T method performed to compare the entry and output of the first lot, and by the independent Student's T method to compare the lots entry and outputs of each batch.

The pH values of the footbath solution increased significantly on the three farms as the lots passed. In farm A the pH increased above the recommended limit from the exit of lot 3. In farms B and C, the pH values increased during the passage of the lots.

In farm B, there was a difference (p≤0.05) between the temperatures at the time of the entry of lot 1 and the exit of lot 3. Farms A and C did not differ from each other. The volume varied in farms A and C. In farm A the volume decreased from the output of lot 4 and in farm C the volume increased at the output of lot 2 and 3. The values of the volume of the bath solutions in relation to the inputs and exits of the lots in farm B, with the smallest number of animals (108), did not differ from each other (p>0.05).

DISCUSSION

The appropriate dimensions of the footbath are part of the important factors for the good management of the footbath. Of the three farms studied, two (A and C) presented a longer length than suggested by some authors. Average length of 2.2 meters, 0.90 meters wide and 15

centimeters deep were described by Bill and Lowell (2007) and Prastiwi *et al*. (2019), however, farms A and C were compatible with the measures suggested by Cook (2017) considering that the length of 3.0 to 3.7 m guarantees at least two strides of the hooves of the pelvic limbs. The length of the footbath in farm B was considered below ideal.

In this study, the three farms used $CuSO_4$ solutions, two of them (B and C) at 5% and farm A at 10% as the chosen antiseptic product. $CuSO_4$ seems to act as the most effective antibacterial agent (Teixeira *et al*., 2010; Speijers *et al*., 2012; Kamiloglu, 2014) and concentrations at 5% or more have been shown to reduce lesions caused by digital dermatitis when compared to animals that do not use the footbath (Solano *et al*., 2017). Different results were observed by Prastiwi *et al*. (2019) when reporting that $CuSO_4$ concentrations around 2% to 4% instead of 5% to 10% reduce soil toxicity and are also effective in preventing laminitis and hull-related injuries.

Although there is no statistical difference between the measurement made in the output from lot 2 to lot 7, the pH of the copper sulfate solution increased gradually at the output of each lot, with the highest average being 4.87 (farm "A", lot 7). The pH and temperature of the footbath solution may change by several factors, including the number of cows passing through the solution and the accumulation of organic matter that is incorporated within the footbath by the defecation of the animal or carried by the hooves (Prastiwi *et al*., 2019). This may explain the significant increase in pH values in the three farms, although the herd in farm B is smaller, as the contamination of the solution with feces, urine and other organic materials occurred, there was an increase in pH, regardless of the concentration of copper sulfate to 10% (farm A) or 5% (farm B). Changes in pH can interfere with the stability of compounds in the solution and impair the interaction between chemical agents and microorganisms, this because the ionization of molecules on the cell surface depends on the pH of the solution (Joklik *et al*., 1994).

Changes in the pH and temperature of the footbath solution during the passage of the cows was verified by Ariza *et al*. (2019) and observed that the temperature variation followed the room temperature. In farms A and C, 537 and 208 cows passed through the footbath respectively and previous studies indicate that copper sulfate solutions from 5% to 10% allow the passage of a maximum of 200 cows (Cook *et al*., 2012; Cook, 2017; Manning *et al*., 2017; Solano *et al*., 2017), so that it does not change the pH of the solution.

To obtain a great result, the pH of the footbath solution must be between 3.4 and 4.5 and when greater than 5.0 loses its effectiveness and should be exchanged, because copper loses its antibacterial function (Potterton *et al*., 2012; Nielsen *et al*., 2016). There was no change of solution in any of the three farms studied during the passage of cows and no farm routinely performs the measurement of pH to verify if it remains within the ideal limit.

Temperature reduced only in farm B. Depending on the antiseptic chosen for the solution, variations in temperature and pH may affect the effectiveness of the product (McDonnel and Russell, 1999) and room temperature and the conditions of the footbath system at each farm should be considered.

An impacting factor of the loss of the volume of the solution is the liquid that splashes out of the footbath as the passage of the animals occurs, which possibly occurred with the volume of the footbath in farm A, which has the largest herd. From the exit of lot 4, composed of 120 cows, in addition to the 218 that had already passed belonging to the previous lots, there was a significant reduction in volume values. These results are similar with those obtained by Ariza's observations *et al*. (2019), that even with the appropriate volume of the solution, after the passage of 200 cows reduced drastically and below the height necessary to fully cover the digits. They also concluded that to ensure partial coverage of the feet, the solution should be changed at least every 100 cows.

The decrease in the volume of the solution by the presence of organic matter (feces and sand carried by the hooves) can transform the footbath into a mud bath, which can alter the permeability of the skin and increase the risk of infection (Palmer *et al*., 2013).

The increase in volume after the exit of lot 2 on farm C seems to be related to the observation that the cows of this herd defecated and urinated too much inside the footbath, a fact that was not prevented by the presence of the foot wash at the entrance. In farms "A" and "B" the animals did not defecate within the footbath. In addition, the volume of the footbath of this farm was lower (10 cm) in relation to farm A and B, both with 15cm, which contributed to the increase of volume with the presence of organic matter. Manning *et al*. (2017) concluded that the presence of foot washer did not influence the number of cows that defecated within the footbath. When they enter the foot washer, cows tend to become slightly apprehensive and can lead to increased defecation and contamination by the time they reach the footbath (Blowey and Chesterton, 2012; Cook *et al*., 2012). The increase in the number of cows that passed through the footbath and defecated influenced the concentration of organic matter in the footbath than the hygiene of the hooves (Ariza *et al*., 2017). The management used in farm B, which consisted of making the cows not delay in the passage of the footbath in order not to defecate, may have been responsible for the no change in depth.

Many variables can influence both the physical and chemical aspects of the footbath, which requires strict attention with how to handle it. Guidance on appropriate management practices remain empirical, many producers use the footbath without professional guidance. According to the results obtained, it is important that other studies are conducted regarding the influence of these aspects on the efficacy of the product adopted for the solution, and consequently on the prevention of foot lesions.

There was no relationship between the different production system of the farms studied on the variables evaluated (P>0.05), but also there was no standardization in the dimensions of the footbaths on the farms, and only three farms were assessed, and these facts represent limitations of the study.

CONCLUSION

The results of this study allowed to conclude that regarding the physical aspects, there was no standardization in the dimensions of the footbaths in the three farms evaluated and the foot washer system did not prevent the presence of organic matter in the footbath. The concentration of 10% copper sulfate solution was not able to inhibit pH changes, which was higher in the solution of the footbaths that passed the largest number of animals. The volume varied both with the number of animals that passed through the footbath and with the deposition of organic matter in the solution.

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