INVESTIGATION OF SOME HOOF DISEASE PREVENTION PRACTICES ON CLAW HORN HARDNESS AND FRICTIONAL PROPERTIES IN DAIRY CATTLE

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ABSTRACT

The purpose of the present research was to investigate the influence of some hoof care practices in dairy cattle (trimming and baths with disinfection solutions) on claw horn hardness and cohesion with concrete floor. Trimmed hooves exhibited reduction in sole horn hardness from 92.75 to 85.125 Shore A, whereas heel horn hardness decreased from 81.75 to 80.375 Shore A. On the other hand, this resulted in increased coefficients of static and dynamic friction from 0.61 to 0.63, and 0.5 to 0.55, respectively, indicating the trimming of hooves increased the walking and stepping safety of cows. The treatment of hooves with 5% disinfection solutions resulted in highest increase in the hardness of all studied hoof zones (walls, soles and heels) after formalin bath, followed by sodium chloride. The 5% solutions of copper and zinc sulfate had a less significant effect on claw horn hardness. The higher concentrations of disinfection solutions resulted in even greater increase in hardness, with highest values after formalin baths again. The treatment with copper sulfate did not exhibit a linear trend in hardness increase although by the end of the study hardness values were higher than initial ones. The increased hardness is essential for coefficients of static and dynamic friction, with evidence for negative correlation between these parameters. The hardness of soles and heels played a significant role for friction coefficient values, as the stability during locomotion depended mainly on the horn quality in these hoof areas.

Key words: *dairy cows, hardness, claw horn, trimming, disinfection solutions, cohesion*

Abbreviations used: *sodium chloride (NaCl), copper sulfate ($CuSO_4$), zinc sulfate ($ZnSO_4$)*

Introduction

Lameness in dairy cows is a clinical sign of hoof and claw diseases, and one of most important problems of cattle husbandry. Losses attributed to lameness are huge and together with infertility and mastitis, this problem is among the commonest causes for culling cows and for poor economic results at farms (Esslemont and Kosaibati, 1997). The strength and resistance of claw horn are essential for the onset of lameness (Penev, 2013, Penev et al., 2014). Factors influencing claw horn strength are selection, nutrition, the environment and horn chemical composition. According to some researchers, the content of zinc (Zn) and copper (Cu) has an important role for increasing the resistance and strength of hooves (Rodin, 1985; Lukyanovski and Gorshkov, 1985; Lukyanovski, 1988; 1997). The authors believe that foot baths with $ZnSO_4$ and $CuSO_4$ solutions have an astringent effect on claw horn, increasing its density. Furthermore, copper is essential for the buildup of disulfide bonds in keratin molecules, which improve horn strength (Underwood, 1981; Baggott et al., 1988). Zinc participates in DNA synthesis during horn keratin synthesis (Baggott et al., 1988). There are several literature reports affirming that sodium chloride (cooking salt) could be also used with success by farmers for disinfection of hooves (Kalinihin, 1982). The advantages of NaCl as compared to traditional disinfectants are its strong antibacterial and astringent properties, the low cost and the better effect on the environment compared to copper and zinc compounds used for animal hooves disinfection.

The purpose of the present research was to investigate the influence of some hoof care practices in dairy cattle such as trimming and baths with disinfection solutions on claw horn hardness and its cohesion with concrete floor.

Material and methods

The study was performed with bovine feet without any pathological deviations, obtained from cattle slaughtered in a slaughterhouse according to all EC welfare norms.

To test the effect of hoof trimming on claw horn hardness, 8 feet were selected, fixed and trimmed by means of a disc installed on an angle grinder. Every hoot was trimmed by at least 3 mm (Fig 1).

Fig 1. Measurement of hoof length before and after trimming

Horn hardness was measured with a durometer Shore A in three hoof areas according to the method of Baggot et al. (1988), i.e. in walls, soles and heels (Fig 2).

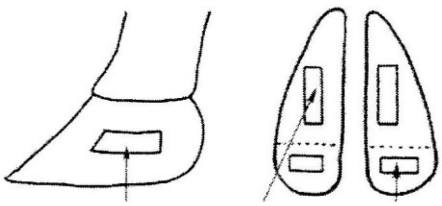


Fig. 2. *Areas of the hooves (walls, soles and heels) where the hardness was determined (Baggott et al., 1988).*

At least 5 measurements were performed in each area, and the highest value was retained.

The coefficients of static and dynamic friction were determined before and after the trimming on dry concrete floor. For this purpose, the tribometer designed by Phillips and Morris (2000) was used. Four pipes (diameter 105 mm; length 200 mm) were attached to a 1 x 0.45 m platform. Four cow feet – two fore limbs and two hind limbs were placed into the pipes. The feet were cut in carpal and tarsal joints, respectively and fixed by auxiliary devices in a way such that after being placed on the floor, the platform weight was carried by soles of the for hooves (Fig. 3). The weight of the platform was 30 kg, and the additional load applied during the study was 150 kg according to the method of Phillips and Morris (2000). The loaded platform was pulled on the floor for determination of static and dynamic friction coefficients.

Fig 3. *Tribometer for determination of coefficients of friction between hooves and floor (Phillips and Morris, 2000)*

The load necessary to move the platform was measured by a dynamometer (Fig. 4) provided by the Centre for Testing and European Certification www.ctec-sz.com.

Fig 4. *Dynamometer for determination of applied force*

The coefficients of static and dynamic friction (μ) were determined as ratio of the minimum force necessary to move the platform (for static friction) or the minimum force needed to maintain the platform in motion (for dynamic friction) and the platform weight The friction coefficients were calculated according to the equation of Phillips and Morris (2000):

$\mu = \frac{F}{M}$ where:

μ – coefficient of friction

F – the load measured by the dynamometer [kg]

M – the weight of the platform and the applied load [kg]

The platform weight was the sum of the weight of the platform itself and the load on it. Static and dynamic friction coefficients were determined on a platform loaded with 150 kg.

To determine the effect of most commonly used disinfectants for hoof disease prevention on horn hardness in Shore a units and the cohesion of hooves and the floor, 5% and 10% working solutions of sodium chloride, copper sulfate, zinc sulfate and formalin were prepared. The hardness was measured in aforementioned zones before the hooves were placed in the solutions. Thereafter, 4 feet were placed for 20 min in each concentration of solution according to the method of Bardanyan (1984). After removal from the solutions, feet were left on a dry surface for an hour and hardness and friction coefficient were measured once again. Then, feet were placed again for another 20 min in solutions, removed, left to dry for one hour and measurements were repeated. The cycle was repeated 5 times for each solution, aiming at reproduce as close as possible the daily disinfection baths of bovine feet. As formalin was volatile and the concentration of formalin solution probably decreased with time, a fresh solution was applied for each experimental cycle.

Data were processed with statistical software (STATISTICA 6). Correlation analysis of the claw horn hardness and friction coefficients was performed. Figures were drawn in MS Excel.

Results and discussion

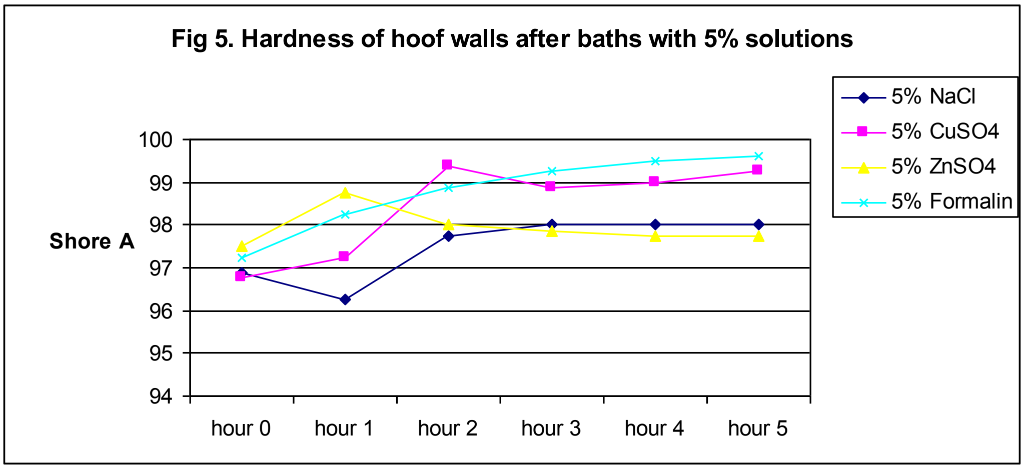
Trimming is one of the obligatory prophylactic activities in dairy cattle husbandry. According to Borissov et al. (2010) it should be done at least twice per year in order to maintain the proper hoof angle for optimal stepping and good contact with farm flooring. Table 1 presents the changes in the coefficients of static and dynamic friction, and sole and heel hardness after hoof trimming.

Table 1. Hardness of hoof soles and heels after trimming and friction coefficients between hooves and floor

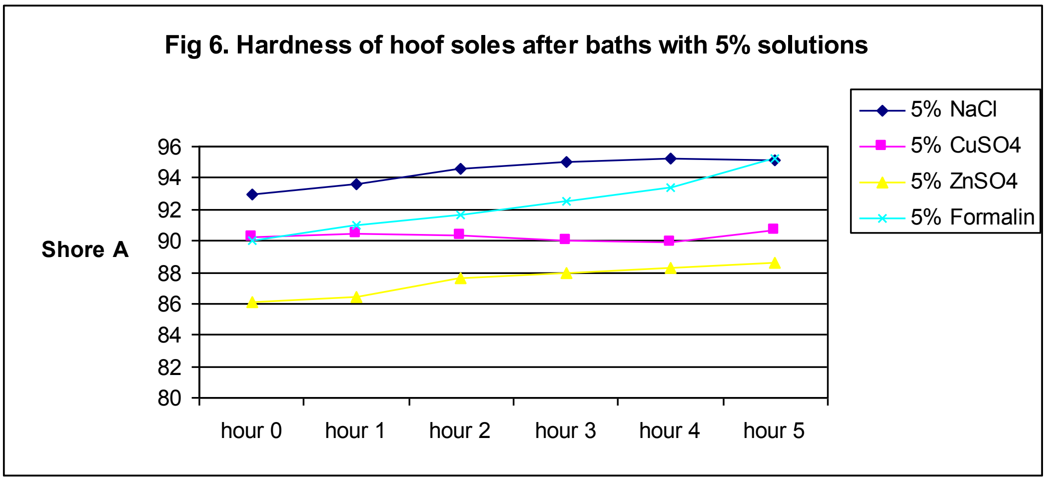
	Hardness of soles, Shore A n = 8	Hardness of heels, Shore A n = 8	Coefficient of static friction n = 3	Coefficient of dynamic friction n = 3
Before trimming	92.75	81.75	0.61	0.5
After trimming	85.125	80.375	0.63	0.55

As the hoof wall is not influenced by trimming, we have not done measurements in this zone. According to the results, trimming resulted in lower horn hardness both in sole and heel zones. This consequently was found to increase static friction coefficient from 0.61 to 0.63 and dynamic friction coefficient from 0.5 to 0.55. Trimming removes the superficial claw horn, which according to our studies was harder that that located deeper. According to Borissov et al. (2010) trimming alters the angle of hoof tubules, the sole surface becomes more regular, which leads to better and safer locomotion on the floor, as confirmed by data fro friction coefficients. The coefficient of dynamic friction between the floor and the hooves is especially imperative for the proper locomotion, it is more important for floor safety and the risk of slipping (Phillips and Morris, 2001). After trimming, this coefficient for dry floor surfaces was within the optimum range ($0.4 < \mu < 0.56$) (Table 1). This allowed cows to move at optimum speed, with optimum stride length and stepping frequency (Phillips and Morris, 2001). These new properties of trimmed claw horn would probably be preserved for 2-3 months, as according to Vermunt and Greenough, (1995), 3 months are necessary for replacement of superficial sole horn with a new one.

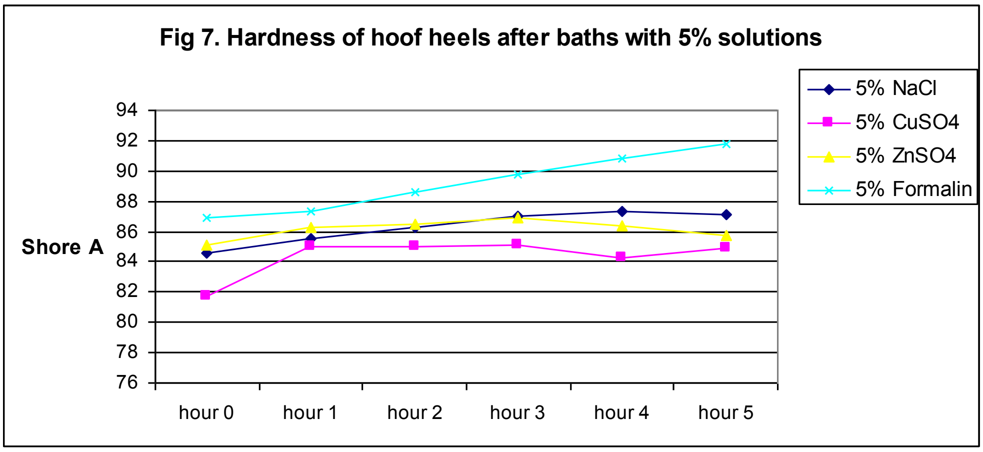
Fig. 5 presents the claw horn hardness in the wall zone after treatment with 5% solutions of tested disinfectants.



It was found out that during the entire period of the study, the hardness of walls increased following baths with 5% formalin. The treatment with NaCl also resulted in higher hoof wall hardness between post treatment hours 1 and 3, which was preserved until the end of the study. This indicates that NaCl is able to increase and preserved horn hardness in the hoof wall area. This is especially important, as this zone bears a major part of the load during the locomotion and should therefore be very strong (Borissov et al. , 2010). The treatment of hooves with $ZnSO_4$ did not result in a steady increase in hardness, even a reduction was observed after the first hour present almost until the end. Copper sulfate ($CuSO_4$) increased initially horn hardness, but after the 2nd hour, a certain decline was observed with regaining maximum values by the 5th hour.

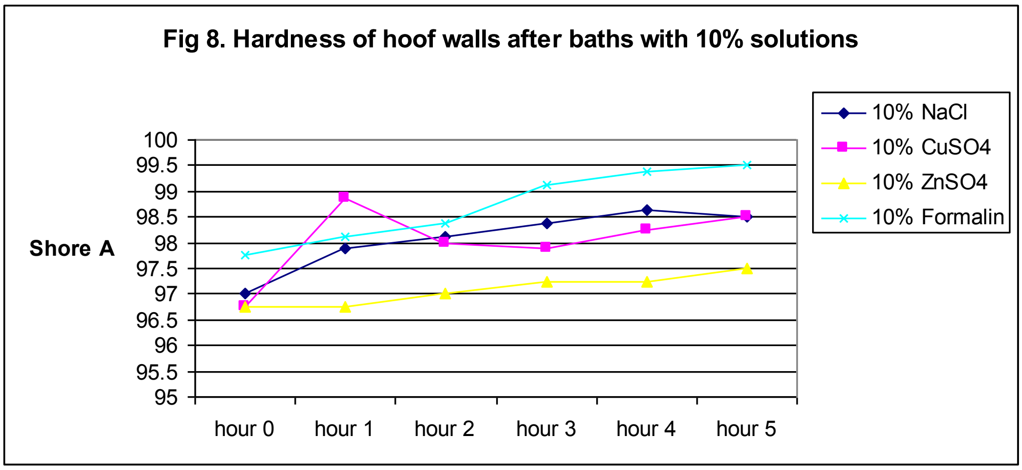


As sole hardness was concerned, formalin and NaCl solutions induced higher hardness during the period of the study (Fig 6). Copper and zinc sulfate solutions did not exhibit any considerable changes in sole hardness. Nevertheless, Penev (2013) proved that the treatment with copper and zinc sulfate resulted in increase in the levels of these elements in the horn, which is essential for its higher resistance against the alkaline pH of manure (Penev, 2013).



Data presented on Fig 7 confirmed the outlined tendencies of most significant increase in heel horn hardness after formalin baths. The initial lower hardness of the horn in this zone probably did not permit significant increase in hardness after treatment with the other 5% solutions. On the other hand, the excessive hardness of formalin-treated heel horn could provoke cracking of the horn, lesions and lameness (Borissov et al., 2010). As per Nuss and Paulus (2006) the horn in this area plays the role of a softening cushion during locomotion, distributing the load and reducing the mechanical tension on hoof soft tissues. Thus, according to the authors, stepping and the contact with the floor are improved. It could be therefore affirmed that the continuous increase in the hardness in this zone of the hoof under the influence of formalin was unsolicited and could induce health problems, respectively lameness.

With respect to the change in hoof wall hardness after foot baths with 10% solutions, the effect of formalin is the most prominent again, followed by NaCl, copper and zinc sulfate (Fig 8).



This tendency was preserved also for the other two claw horn areas – soles and heels (Fig. 9 and 10).

Fig 9. Hardness of hoof soles after baths with 10% solutions

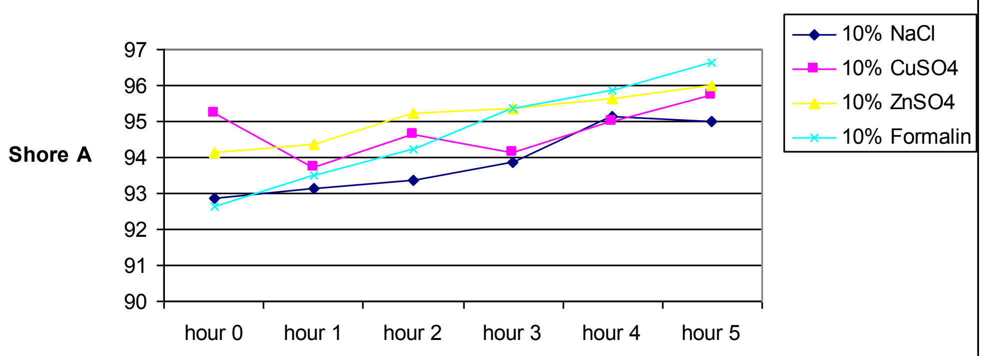
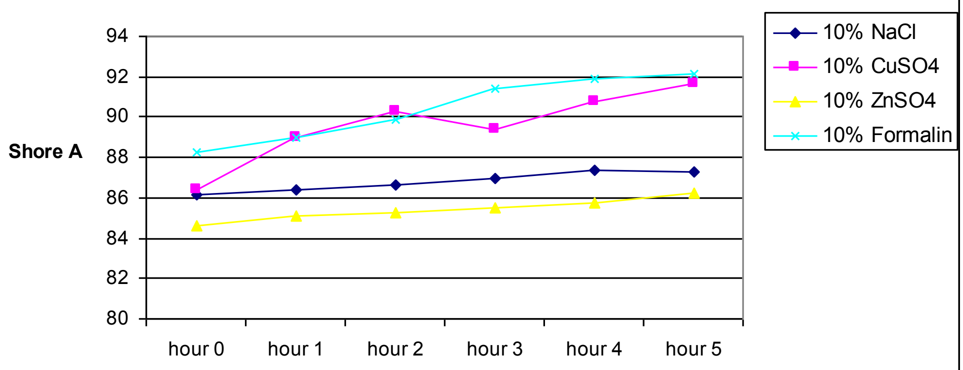


Fig 10. Hardness of hoof heels after baths with 10% solutions



The comparison of heel and sole horn hardness after treatment with NaCl, copper and zinc sulfate revealed that copper sulfate baths yielded contradictory results, with peaks and drops (Fig. 9 and 10). According to Bardanyan (1984) formalin and copper sulfate applied as 10% solutions exerted a positive impact on claw horn of healthy cows and heifers through increasing in its hardness. In our study, these results were confirmed fully only for formalin and at a lesser extent, for copper sulfate. The selection of an appropriate means for hoof treatment should take into consideration not only the changes occurring in horn hardness, but also some details about the storage, way of preparation, duration of use, efficacy against bovine hoof pathogens and last but not least, the costs. According to Borissov et al. (2010) formalin, zinc and copper sulfate are good as efficiency against pathogens is concerned, especially if used on a rotational principle. The authors stated that formalin has some drawbacks, i.e. the terms of use as it is volatile and evaporates quickly especially during the summer. This property together with the proved carcinogenic effect for people result in more and more rare use of the compound in cattle farming. In modern cattle farms, the preservation of good organoleptic properties of milk require observation of some conditions, requiring the performance of foot disinfection baths at a safe distance from milk parlours. Bardanyan (1984) states that foot baths with 10% formalin could be successfully used in cows with hoof diseases with achievement of a positive effect through reduction of horn water content. The cost of prophylaxis of hoof diseases in cows is also important. Table 2 presents the price of all tested disinfectants in EUR, as well as the price of 1 L 5% or 10% solutions.

Table 2. Cost of tested foot disinfection baths

Preparation for hoof disease prevention	Price per 1 kg/l, €	Price of 1 L 5% solution, €	Price of 1 L 10% solution, €
NaCl	0.1	0.005	0.01
$CuSO_4$	3	0.15	0.3
$ZnSO_4$	5	0.25	0.5
Formalin	7	0.35	0.7

As could be seen from Table 2, the difference between the prices of tested disinfectants is very big, with sodium chloride being the cheapest, and the formalin- the most expensive product. Having in mind the volatility of the latter and the need for more frequent replacement of solutions, it could be affirmed that its daily use at cattle farms is not justified. The other two compounds - $CuSO_4$ and $ZnSO_4$ are relatively expensive. For an average-size pool of 330 L for a farm with 165 cows and 540 L for a farm with 260 cows (Borissov et al., 2010), and 3 to 5 weekly treatments, the cost differences of the various disinfection means are substantial and would inevitably influence the farm budget. With this respect, sodium chloride is a very good alternative to traditional disinfectants. It should be also outlined that sodium chloride is well-acknowledged for its antibacterial effect against a lot of microorganisms. Yet, its bactericidal properties should be also tested against specific pathogens causing hoof diseases in cattle. The environmental effects are also very important. Out of all tested disinfectants, sodium chloride is the safest for animals, men and the environment. Formalin is volatile and pollutes air, and hoof copper and zinc via the manure could accumulate in soils, which are regularly fertilised with manure. Used copper sulfate foot baths are considered industrial waste and must be treated as such. However, as soon as the foot bath material is mixed with manure it no longer classifies as industrial waste and can be disposed of with the manure into a manure pit (Klinberg, 2005). Although the copper solution is diluted when mixed with manure, there is still great potential for copper build up in the soil and implications for harm to wildlife when the manure is spread on the fields. The average five percent copper sulfate footbath contains 62 gallons of water and 26 pounds of copper sulfate (Desnoyers et al., 2008). This amounts to about six and a half pounds of copper being added to the soil with each foot bath disposal, which can lead to exceedence of the maximum loading rate for soil copper in as little as five years (Epperson & Midla, 2007). It is extremely important for dairies that use copper sulfate to have soil tests done regularly to check for copper loading.

Table 3 depicts the correlations between claw horn hardness after treatment with 5% and 10% working solutions of disinfectants and the coefficient of static friction. The strongest relationships were observed for formalin-treated hooves. This is explained by the observed increase in horn hardness under the influence of formalin. At all hoof zones, negative correlations were observed between the hardness and static friction coefficients after treatment with all tested compounds and concentrations. Data showed that soles and heels were the most important for cohesion, except for 5% copper sulfate.

Table 3. Correlation coefficients between claw horn hardness and coefficients of static friction after disinfection baths of hooves

5% solutions				
Hoof zone	NaCl	$CuSO_4$	$ZnSO_4$	Formalin
Walls	- 0.18	- 0.49*	- 0.01	- 0.49*
Soles	- 0.35*	- 0.01	- 0.29*	- 0.71*
Heels	- 0.30*	- 0.40*	- 0.08	- 0.62*
10% solution				
	NaCl	$CuSO_4$	$ZnSO_4$	Formalin
Walls	- 0.26	- 0.13	- 0.16	- 0.45*
Soles	- 0.46*	- 0.20	- 0.29*	- 0.68*
Heels	- 0.21	- 0.35*	- 0.27	- 0.61*

* - $P < 0.05$

This is due to the fact that these hoof areas are in contact with the floor and therefore, their higher hardness reduces the cohesion. The hardness of hoof soles is of particular significance for stability on the floor, as was clearly suggested by the moderate to high correlation coefficients between parameters. Exceptions from this statement were 5% and 19% copper sulfate baths which resulted in higher correlation coefficients between static friction and the hardness of walls and heels. This could be due to the more extensive penetration of copper salts in these zones of claw horn. According to some authors, the higher Cu and Zn contents of claw horn should not be interpreted as a factor determining a greater strength of the hoof (Baggott et al., 1988). The authors observed higher hoof Cu content in lame vs healthy cows. Similarly to correlations between the static friction coefficient and hardness, the strongest relationships for the coefficient of dynamic friction were detected for hooves treated with formalin (Table 4). With respect to hoof area, the strongest negative correlation for 5% solutions was found out for soles. Again, hooves bathed in copper sulfate were an exception, due to decreased or increased hoof hardness after treatment with this disinfectant.

Table 4. Correlation coefficients between claw horn hardness and coefficients of dynamic friction after disinfection baths of hooves

5% solutions				
Hoof zone	NaCl	$CuSO_4$	$ZnSO_4$	Formalin
Walls	- 0.09	- 0.24	0.08	- 0.46*
Soles	- 0.13	- 0.09	- 0.29*	- 0.66*
Heels	- 0.12	- 0.08	- 0.07	- 0.61*
10% solutions				
	NaCl	$CuSO_4$	$ZnSO_4$	Formalin
Walls	- 0.31	- 0.11	- 0.16	- 0.45*
Soles	- 0.45*	- 0.15	- 0.25	- 0.67*
Heels	- 0.20	- 0.39*	- 0.28	- 0.61*

* - $P < 0.05$

The highest negative correlation coefficients after treatment with 10% solutions were registered for sole horn, and after copper sulfate bath – for heel horn (Table 4). Like the static friction coefficient, higher copper sulfate concentration provoked a higher heel hardness and hence, lower cohesion. Data from Table 4 showed that higher concentrations of solutes resulted in stronger correlation between hardness and the coefficient of dynamic friction, except for formalin baths.

This is especially important as the dynamic friction coefficient is essential for the locomotion stability of cows (Phillips and Morris, 2001).

Data from Table 3 and 4 allowed assuming that formalin was the only to provoke a significant increase in claw horn hardness in all tested hoof zones leading to lower coefficients of static and dynamic friction. Sodium chloride, copper and zinc sulfate increased predominantly sole and heel horn hardness. The most reliable criterion for evaluation of hoof hardness changes and consequently, of coefficients of static and dynamic friction under the influence of chemical means for hoof disease prophylaxis as suggested by our results, is the claw horn hardness in sole and heel regions.

Conclusion

Hoof trimming resulted in lower horn hardness in the area of soles and heels, and subsequently, increased coefficients of static and dynamic friction. The treatment of hooves with 5% disinfection solutions resulted in highest increase in the hardness of all studied hoof zones (walls, soles and heels) after formalin bath, followed by sodium chloride. The 5% solutions of copper and zinc sulfate had a less significant effect on claw horn hardness increase. The higher concentrations of formalin, sodium chloride and zinc sulfate disinfection solutions resulted in even greater increase in hardness. The treatment with copper sulfate did not exhibit a linear trend in hardness increase. The relationship between horn hardness and coefficients of static and dynamic friction after the disinfection baths demonstrated that sole and heel hardness was the most important for friction between hooves and the floor. For all tested disinfectants, the higher hardness resulted in stronger negative correlation with friction coefficients. The lack of linear relationship between claw horn hardness after copper sulfate baths could be due to some specific features of horn chemical structure and the effect of copper sulfate.

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