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Investigations on friction coefficients of cow hooves with different dairy farm floor types

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Abstract. The investigation was performed in three Bulgarian free-stall cattle farms with different flooring types. The floor of farm A was covered with two rubber mat types, with and without abrasion lining. At the other two farms, floors were made of grooved concrete which was used for 6 years (farm B) and for 4 years (farm C). The purpose of the investigation was to determine the friction coefficients on the different floorings with a tribometer described by Phillips and Morris (2000) and the influence of some factors as usage period, presence of manure and water on the floor. The coefficient of static friction of dry floors at the studied farms varied from 0.46 on the concrete floor at farm B to 0.59 on the rubber floor with abrasion lining. It indicated that dry floors at the surveyed farms provided good safety for standing animals. The dynamic friction of dry floors was the lowest at farm B – 0.44, and the highest on the rubber floor with abrasion lining at farm 1 – 0.56. When water was spilled on the floor, static friction coefficients of all studied floorings decreased except for the rubber floor with abrasion lining, where it increased up to 0.61. The dynamic friction coefficients were lower when all floors were wet. The lowest dynamic friction coefficient was determined on the floor at farm B – 0.39, which is under the critical minimum. This was attributed to its longer usage and thus, its wearing and smoothing. Static friction coefficients on manure-covered floors varied from 0.4 to 0.49. The lowest dynamic friction coefficient (0.36) was measured on the floor at farm B, and the highest (0.46) – on the rubber floor with abrasion lining, farm A.

Keywords: coefficient of dynamic friction, coefficient of static friction, hooves, rubber floor, concrete floor

Introduction

Locomotion is an essential part of the natural behaviour and welfare of dairy cows. It has a beneficial effect on the cows’ health (Gustafson, 1993; Gergovska, 1992). Nevertheless, the used cattle production systems often limit or impede the locomotory activity of dairy cows (Fraser and Broom, 1997). The flooring type is one of the most important elements of the cows’ locomotion at free-stall farms (Stefanowska et al., 1998). Most technological alleys at cattle farms are made of concrete, because it is hard, cheap and acceptable with regard to hygiene maintenance. The hardness, abrasive properties and the inadequate friction of concrete floors however suggest that concrete predisposes cows to hoof diseases (Webb and Nilsson, 1983; Bergsten and Frank, 1996). Poor hygiene on the floor with strong manure mass may be a factor for the development of lameness in cows, reducing the amount of fat in claw horn, and thus its strength (Penev, 2013; Penev et al., 2014). Improper environmental conditions are some of the most important conditions for the development of lameness (Mitev et al., 2011; Penev et al., 2012). Lameness as a clinical symptom of the disease of the legs and feet means loss of productivity and poor reproductive conditions (Mitev et al., 2011; Mitev et al., 2012; Penev, 2013).

Herlin and Drevermo (1997) established that rearing cows in a premise with grooved concrete throughout the year had a negative impact on the locomotory system of animals. The poor quality of the floor could influence the social and sexual behaviour of cows, as well as their welfare (Zeeb, 1983; Benz, 2002; Mitev et al., 2012).

Concrete used for lining alleys at free-stall barns is usually considered as too slippery for normal locomotion (Webb and Nilsson, 1983; Faull et al., 1996). The movement of the cow is influenced both by the rough or the soft surface of the floor (Telezhenko and Bergsten, 2005; Rushen and de Passillé, 2006). With their use, concrete floors become smoother and thus slippery for cows, enabling falling down and injury (Schlichtung, 1987). The presence of manure mass (MM) or water on the floor is another important factor making cows walk with unnatural gait (Albutt et al., 1990).

The purpose of the investigation was to determine the coefficients of static and dynamic friction on different states of two rubber floorings and two types of concrete floors used for a different period in free-stall barns for dairy cows.

Material and methods

The investigation was performed at 3 cattle farms. Farm A. The farm has freestall barn with individual cubicles for 200 dairy cows. The cubicle surface is made of concrete, bedded with straw. Alleys were covered with two types of rubber mats. Near the waterers, and at the end of alleys where cows usually change the direction of walk, the concrete floor is covered with rubber mats with abrasion particles (pediKURA - KRAIBURG®), which are designed to wear the hooves of animals. The other part of alleys is covered with rubber mats without abrasion lining (KURA P - KRAIBURG®). The cleaning of manure is performed with automated electrically-driven scrapers.

Farm B. The cows are reared indoor in a 180-cow freestall barn with individual cubicles for rest. The barn has been used since 2006 – for 6 years. Technological alleys in the barn are made of grooved concrete, and the cubicles – bedded with rubber mats. The cleaning

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is performed with a delta scraper.

Farm C. The cows are reared indoor in a 478-cow freestall barn with individual cubicles for rest, built in 2008, i.e. used for 4 years. The barn is divided in two parts by a feeding alley and in each part cubicles are arranged in 3 rows. Technological alleys are made of grooved concrete, and the cubicles – bedded with composted manure and straw. The cleaning is done with a delta scraper.

The coefficients of static and dynamic friction were determined by a modification of the tribometer described by Phillips and Morris (2000). On a 1 x 0.45 m platform, four pipes 105 mm in diameter and 200 mm long were attached. Into the pipes, four cow’s feet (two forelimbs and two hindlimbs) obtained from a slaughterhouse were inserted. A cow with a normal gait was chosen, without signs of lameness and whose hooves were with normal shape. The carpal and tarsal joints were removed and the other parts of the limbs and hooves were fixed into the pipes by auxiliary devices in a way that the weight of the platform was carried by the sole surface of the hooves after placing it on the floor (Figure 1).

The weight of the thus prepared platform was 30 kg, and during the trials, an additional 150-kg weight was added (Figure 2). The total weight of the tribometer therefore consisted of the platform weight plus the added weight.

According to Phillips et al. (1998) and Phillips and Morris (2001), the application of a 150-kg weight on the platform was sufficient for objective evaluation of the coefficients of friction between cows and the floor. For determining the static and dynamic friction coefficients, the loaded platform was pulled on floor surface from the caudal part in order not to bend the joints over the hooves and to preserve their contact with the floor. The force necessary to move the platform was measured by means of a dynamometer provided by the Centre for Testing and European Certification www.ctec-sz.com.

The coefficients of static and dynamic friction between hooves and the tested floors were determined when they were dry, wet or covered with manure mass. The coefficients of static and dynamic friction (μ) were determined as the ratio between the minimum force for moving the platform and the platform weight (coefficient of static friction) and the ratio between the minimum force needed to maintain the platform in motion and the platform weight (coefficient of dynamic friction).

The coefficient of friction was calculated according to the formula:

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

where $\mu$ is coefficient of friction, $F$ – the load recorded by the dynamometer (kg), $M$ – the platform weight with the applied load (kg).

Data were statistically processed by the STATISTICA 6 software, and graphs were made in Microsoft EXCEL.

### Results and discussion

Figure 3 presents the coefficients of static and dynamic friction on dry floors at farms. It was established that all coefficients of static friction were between 0.4 < $\mu$ < 0.6. According to Phillips and Morris (2001) they are an important parameter of floor friction properties and therefore, locomotion safe.

The dynamic friction coefficient is more important for the safety of farm flooring and the probability of slipping for dairy cows (Phillips and Morris, 2001). On dry floors it varied within an optimal range...
The measured values indicated that cows could walk with an optimal speed, stride length and stride frequency (Phillips and Morris, 2001).

The data presented on Figure 4 demonstrated that static friction coefficients on wet floors were lower compared to those on dry floors. Only for the rubber mat with abrasion lining, the static friction coefficient increased when it was wet. There were statistically significant differences between values measured for this flooring type (P<0.05) and all other tested floorings for both coefficients of static and dynamic friction. The rougher surface of this floor due to abrasive particles probably counteracted the effect of water on friction forces. Phillips and Morris (2000) and Franck et al. (2007) also reported higher coefficient of friction of wet vs dry floor in support of our findings. When the floor surface was rough enough, the water was retained among abrasive particles and did not influence negatively the friction of hooves and floor (Franck et al., 2007).

For all compared floorings except for the concrete floor at farm B, the presence of water did not exert substantial negative effect on friction coefficients. The floor at farm B was used for 6 years (since 2006) or 2 years more compared to the concrete floor at farm C. This probably resulted in more significant wearing of the flooring at farm 2 and hence, the statistically significantly lower coefficients of static and dynamic friction vs those measured at farm C. According to Web and Nilsson (1983) a friction coefficient of 0.4 is critical and lower values increase exponentially the risk of slipping of cows. According to our experiments, the water on the floor at farm B reduced the coefficient of dynamic friction to values which could have unfavorable consequences for animals. Therefore, the water on farm floorings acts as a lubricant by reducing the friction between the cow’s hoof and the floor and increasing the risk for slipping (Nilsson, 1988).

The presence of manure mass on floorings reduced both coefficients of dynamic and static friction on all tested floorings (Figure 5). For the rubber mat without abrasion lining, and the concrete floor at farm B, static friction coefficients were under the critical minimum. The low coefficient of static friction (μ<0.4) in the

![Figure 4. Coefficients of static and dynamic friction on wet floorings (a,b,c – the differences between columns were statistically significant at P < 0.05)](image)

![Figure 5. Coefficients of static and dynamic friction on manure-covered floorings (a,b,c – the differences between columns were statistically significant at P < 0.05)](image)

**Conclusion**

Dry floors at the three surveyed farms provided an optimal friction and safety for animals. The rubber flooring at farm A had the highest friction coefficients. The wetting of the rubber floor with abrasion lining increased its friction properties as compared to the dry state due to abrasive particles included. The concrete floor at farm B exhibited a coefficient of dynamic friction below the critical minimum when covered with either water or manure, due to the wearing during its use. Rubber floorings with abrasion lining were with excellent coefficients of static and dynamic friction even when they were covered with manure.
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