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Influence of floor surface and access to pasture on claw characteristics in dairy cows kept in cubicle housing systems

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Summary

This study aimed at investigating the effect of the floor type used in the walking area of cubicle housing systems and of access to pasture on claw dimensions and claw shape in dairy cows. Data were collected on 36 farms, 12 farms each fitted with mastic asphalt, slatted concrete or solid rubber flooring. With each floor type, cows on half of the farms had access to pasture in summer. The farms were visited three times at intervals of about 6 months and data were collected from 10 cows during each visit. Net growth of the claw horn was highest on rubber flooring and lowest on mastic asphalt. On all floor types, claw angles were larger after the winter period and smaller after the summer period. With regard to claw shape, floor type had an effect on the occurrence of flat, concave and overgrown claw soles. In conclusion, none of the investigated floor types was clearly superior to the others with regard to claw dimensions and claw shape, and access to pasture during summer (median 4 h per day) had only little influence on the investigated claw characteristics.

Keywords: claw dimensions, claw shape, dairy cows, floor type, pasture

Einfluss des Bodens und des Weidegangs auf die Klauendimensionen und die Klauenform von Milchkühen in Boxenlaufställen

Die Untersuchung hatte zum Ziel, den Einfluss des Bodens im Laufbereich und des Weidegangs auf die Klauendimensionen und die Klauenform von Milchkühen zu bestimmen. Die Datenerhebung fand auf 36 Betrieben mit einem Boxenlaufstall statt, von denen je 12 im Laufbereich Gussasphalt, Betonspalten oder planbefestigte Gummimatten eingerichtet hatten. Bei jeder Bodenqualität hatten die Kühe auf der Hälfte der Betriebe im Sommer Weidegang. Auf jedem Betrieb wurden zu 3 Zeitpunkten in einem Abstand von rund 6 Monaten Daten an 10 Kühen erhoben. Das Klauenwachstum war auf Gummiboden am stärksten und auf Gussasphalt am schwächsten ausgeprägt. Unabhängig vom Bodentyp waren die Klauenwinkel am Ende der Winterperiode grösser und am Ende der Sommerperiode kleiner. Der Bodentyp hatte auch einen Einfluss auf das Auftreten von flachen, konkaven und überwachsenen Klauen. Insgesamt erwies sich aber keiner der Bodentypen als deutlich vorteilhaft, und der Weidegang (Median 4 Stunden pro Tag) hatte nur geringe Auswirkungen auf die Klauendimensionen und die Klauenform.

Schlüsselwörter: Klauendimensionen, Klauenform, Milchkühe, Bodentyp, Weide

Introduction

Claw dimensions of dairy cows are influenced by the type of the floor provided in the walking area of loose housing systems (Vermunt and Greenough, 1995). Floor types differ regarding softness and abrasiveness, and these characteristics have an influence on claw dimensions and shape. For example, rubber floor is a soft floor that causes only little abrasion (Kremer et al., 2007). Mastic asphalt and slatted concrete in contrast are hard floors, which are more or less abrasive depending on their quality and age. Rubber flooring in cubicle housing systems is a relatively new floor type, and its effect on claw characteristics has hardly been investigated (Benz, 2002; Kremer et al., 2007; Telezhenko et al., 2009). Similarly, there are only a few studies dealing with the influence of mastic asphalt on claw characteristics (Telezhenko et al., 2009). The current study therefore aimed at systematically investigating the effect of three floor types (mastic asphalt, slatted concrete and solid rubber) on claw dimensions (net growth, changes in claw angle) and claw shape (in particular occurrence of flat soles, concave soles) in dairy cows kept in cubicle housing systems. Additionally, claw width was recorded because disproportionate asymmetry in claw width between lateral and medial claw is thought to reflect overload (Ossent et al., 1987). Previous studies relating to rubber and mastic asphalt flooring were typically carried out on a single farm. In contrast, data were collected on 36 farms in the present study to allow a generalisation of results. By comparing the claws of cows kept on farms with and without access to pasture in summer, the study also investigated whether outdoor exercise on pasture could mitigate the negative effects of flooring in the indoor walking area on claw characteristics.

Animals, Material and Methods

Animals and housing conditions

The study was conducted on 36 dairy farms with cubicle housing systems and an average herd size of 52 lactating cows (range 18–140 cows). On 12 farms each the floor surface in the indoor walking area of the housing system consisted of mastic asphalt, slatted concrete or solid rubber. With each floor type, cows on half of the farms had access to pasture in summer for several hours a day (2.5 to 8 h, median 4 h). In addition, cows on all 18 farms with and 4 farms without access to pasture had access to an outdoor run with a floor typically made of solid or slatted concrete (Haufe et al., 2012).
Cows (Brown Swiss, Holstein Frisian, Red Holstein, Simmental and crossbreeds) were milked twice a day with the exception of one farm with slatted concrete floor and access to pasture that used an automatic milking system. Average milk yield on the study farms amounted to 7'928 kg. A selection criterion for farms chosen for this study was that the floor in the cubicle housing was in an adequate condition (e.g. not too slippery, not too rough), i.e. farms with a known floor problem were not included. Similarly, farms known to have major problems with claw health or other aspects of animal health were not considered for this study.

Assessment of claw characteristics

To assess claw dimensions and claw shape, 10 cows with parity 2 to 6 were selected on each farm. If cows left the herd during the study (21 cows) they were replaced by an animal as closely comparable in respect to parity, breed and lactation stage as possible. The farms were visited three times at intervals of about 6 months at the end of the winter indoor housing period and at the end of the summer period. On farms with access to pasture, data collection started at the end of the summer period in autumn 2005. Farms without pasture were first visited at the end of the winter period in spring 2006. For organizational reasons, one farm with a slatted concrete floor (with access to pasture) as well as one farm with mastic asphalt (without access to pasture) was only visited twice, and one farm with a slatted concrete floor (without access to pasture) was only visited once.
On farms with access to pasture, data reflecting the winter and the summer period were recorded in spring before the pasturing season and in autumn before the start of the indoor period, respectively. For the farms without access to pasture, we counted all claw trimmings until the 15th June as belonging to the winter period and all claw trimmings until the 15th December as belonging to the summer period.
Claw assessments were conducted on a total of 381 cows (10 cows/farm plus 21 replacement cows). Claw inspections were always carried out on the occasion of routine claw trimming. Claw assessments of cows that had required claw trimming before the routine claw trimming were excluded from the analysis (103 assessments made on 85 cows), so that 892 observations of 381 cows were analysed.
Claw length and claw angle were measured on both claws of the left front and right hind limbs. For the analyses, only the relative change in horn length (growth/wear) and the change in claw angle were of interest. Claw growth and change in claw angles were expected to be influenced by the inter-trimming interval, because these two measurements directly depend on those aspects of the claw that are shaped by the claw trimming itself. Claw length and claw angle were thus measured after each claw trimming and before the consecutive claw trimming. Then, the differences of claw length and angle between two claw trimming events were calculated and standardized per month to consider the influence of the inter-trimming interval.
Claw length was measured with a measuring tape along the dorsal border from the apex of the claw to the proximal end of the claw capsule at the coronary band (Fig. 1, A). Claw angle was measured while the cow was standing with a Single Axis Inclination Sensor KAS804-01 and -02 (Kelag®) installed in a metal box (80 × 55 × 18 mm). The claw angle was measured in the centre of the dorsal wall of the claw (Fig. 1, B) with the short side of the Single Axis Inclination Sensor. Sole width was recorded with a vernier calliper at the widest part of the claw (including overgrown sole horn) before the claw trimming (Fig. 1, C).
The appearance of the sole was assessed for each claw. A distinction was made by visual inspection between flat soles without any concavity and concave soles with a loose sole horn. A given cow was assigned to one of these two categories if more than two claws were either flat or concave. Cows not meeting this criterion were considered not to have either flat or concave soles. In addition to the occurrence of flat and concave claws, the occurrence of overgrown sole horn at the sole was recorded. Overgrowth was defined as excessive growth of the sole horn extending over the inter-digital space. A given cow was considered to have overgrown claw soles if at least one of her claw soles was overgrown.

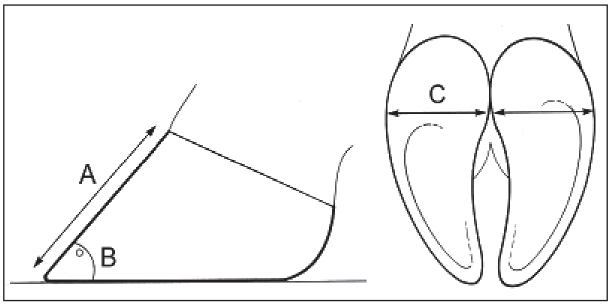

Figure 1: Schematic drawing of claw measurements: Claw length (A), claw angle (B) and sole width (C) (modified from Kloostermann, 1997).

Statistical analysis

Linear mixed-effects models (Pinheiro and Bates, 2000) with general positive-definite covariance matrices were used to evaluate the data for claw characteristics (claw length differences, claw angle differences, sole width) in R 2.1.1 to 2.6.1 (R Development Core Team, 2006). The fixed effects in these models were floor type, access to pasture, the period (summer and winter period), the limb (front left and rear right limb), the claw (lateral and medial), the breed and the lactation group (lactation number ≤ 4 and > 4). All the models included all possible interactions between floor type, access to pasture and period. In the models of claw length and angle, all interactions between floor type, access to pasture and limb and all interactions between limb, claw and period were additionally included. In the model of sole width, all interactions between floor type, limb and claw were also considered. Farm visit nested in limb, nested in cow and farm, was used as the random effect in all models. We started out from the models as described above and reduced terms in a step-wise backward manner until only significant terms and main effects remained in the model. In this process we used $P > 0.01$ as the criterion.

The occurrence of concave soles, flat soles and overgrown claw horn per cow was analysed using logistic regression. Each model aimed at estimating the risk as reflected by the odds-ratios of one of these findings in dependence on floor type while controlling for other variables (generalised linear mixed-effects model based on the quasi-binomial distribution; Venables and Ripley, 2002). In all models we included the floor type, access to pasture, the period and all possible interactions of floor type, access to pasture and period as explanatory variables. Farm visit nested in farms was included as the random effect.

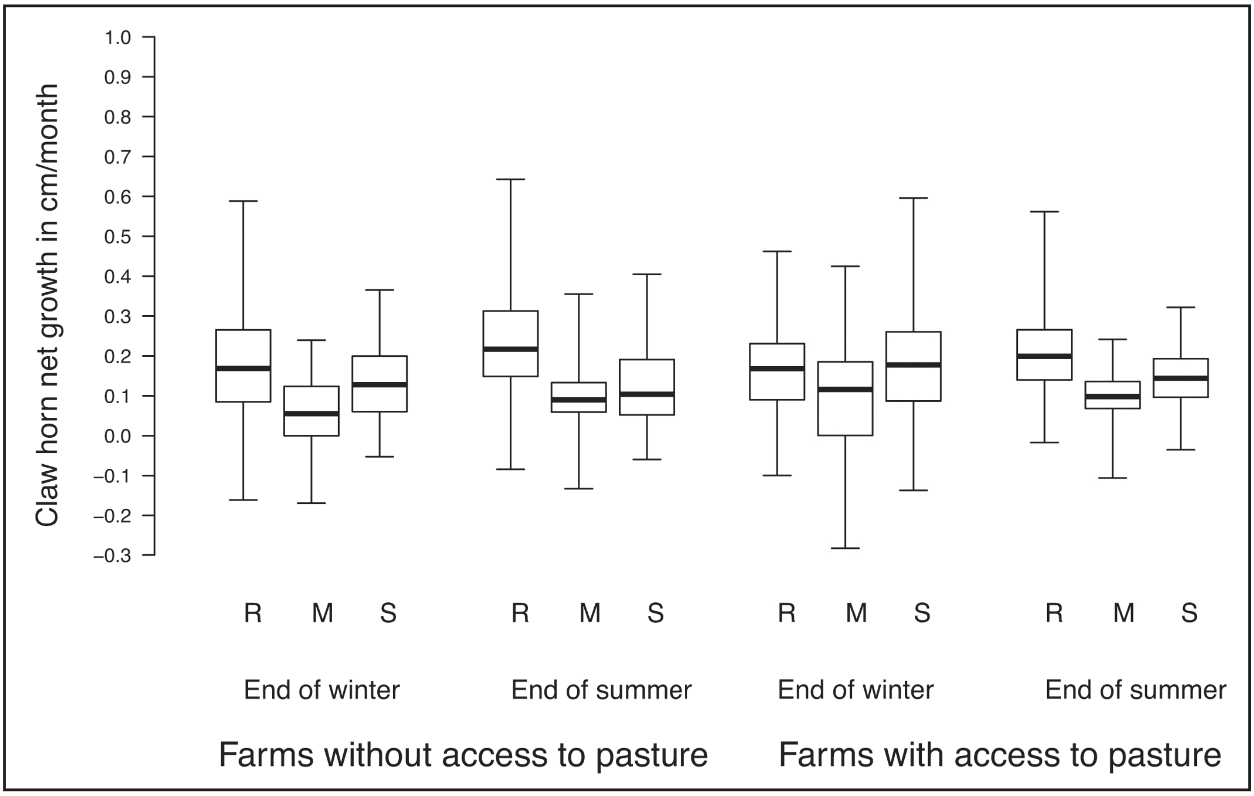

Figure 2: Net growth of the claw horn per month of cows kept in cubicle housing systems with different floor types (R: Rubber floor, M: Mastic asphalt, S: Slatted concrete floor) and with or without access to pasture measured at the end of the winter indoor housing period and at the end of the summer pasture period. In the boxplots, the box shows 50 % of the data, the vertical line indicates the range and the horizontal line the median.

Results

Claw dimensions

Both in the winter and the summer period stronger net claw growth was found on rubber floors and slatted concrete than on mastic asphalt (Fig. 2). The differences between the seasons decreased from rubber to mastic asphalt and to slatted concrete floors (interaction of period × floor type: $F_{2,\,1242} = 9.65$, $P < 0.0001$). Access to pasture did not influence net claw horn growth ($F_{1,\,29} = 0.26$, $P = 0.615$). The medial claw had a higher net claw growth than the lateral claw ($F_{1,\,1242} = 14.66$, $P < 0.0001$). Neither breed nor lactation group influenced claw length differences.

On all farms, claw angles were larger after the winter period and smaller after the summer period. Differences between claw angle values measured on subsequent farm visits were more extreme towards larger differences in winter and smaller differences in summer on farms with access to pasture than on farms without access to pasture (interaction of access to pasture × period: $F_{1,\,1184} = 63.45$, $P < 0.0001$). In the winter period the greatest claw angle differences were found on mastic asphalt and these

Table 1: Number of observations, prevalence, odds ratios (OR) and their 95 % CIs as estimated by the model, and df, t, and p-values for flat, concave and overgrown soles.

Risk factor	N	Prev. (%)	OR	95 % CI	df	t	p
Occurrence of flat soles							
Interaction of floor type and period							
Rubber floor at winter	125	10.0	1				
Rubber floor at summer	171	35.9	1.5	0.4–5.9	65	0.62	0.54
Mastic asphalt at winter	142	77.5	131.7	32.9–526.7	32	7.01	< 0.001
Mastic asphalt at summer	168	41.1	17.4	4.6–66.6	65	–2.81	0.007
Slatted concrete at winter	127	5.1	0.5	0.1–2.7	32	–0.78	0.44
Slatted concrete at summer	159	4.8	0.4	0.1–1.9	65	–0.73	0.47
Access to pasture							
Without access to pasture	423	25.1	1				
With access to pasture	469	23.2	0.9	0.04–2.2	32	–0.15	0.88
Occurrence of concave soles							
Floor type							
Rubber floor	296	44.9	1				
Mastic asphalt	310	10.0	0.08	0.02–0.3	32	–3.93	< 0.001
Slatted concrete floor	286	52.4	0.38	0.1–1.1	32	0.91	0.37
Access to pasture							
Without access to pasture	423	34.5	1				
With access to pasture	469	35.8	1.1	0.4–3.1	32	0.20	0.84
Period							
Winter	394	27.9	1				
Summer	498	41.0	2.7	1.5–5.0	67	3.17	0.002
Occurrence of overgrown soles							
Floor type							
Rubber floor	296	8.4	1				
Mastic asphalt	310	20.0	3.2	1.3–8.3	32	2.56	0.02
Slatted concrete floor	286	17.1	2.5	1.0–6.5	32	1.96	0.05
Access to pasture							
Without access to pasture	423	16.1	1				
With access to pasture	469	14.5	0.7	0.3–1.5	32	–0.92	0.36
Period							
Winter	394	10.4	1				
Summer	498	19.1	2.2	1.3–3.7	67	2.9	0.005

were decreasingly smaller on slatted concrete floors and on rubber floors, whereas in the summer period these differences were smaller and much more comparable among floor types (interaction of period × floor type: $F_{2,\,1184}$ = 6.31, P = 0.019). The differences between claw angle values measured on subsequent farm visits were not influenced by limb, claw, breed or lactation group.
On all farms the lateral claw was found to be wider than the medial claw both on the front and rear limb, but the reduction in width from the lateral to the medial claw was more pronounced in the rear limb (interaction of limb × claw: $F_{1,\,701}$ = 199.87, P < 0.0001). The disproportion between the lateral and medial claw was not influenced by floor type. Both on farms with and without access to pasture claws were wider in summer than in winter, though the increase in claw width from winter to summer was greater on farms with access to pasture (interaction of access to pasture × period: $F_{1,\,2194}$ = 6.90, P = 0.0087). The claw width of cows kept on farms without access to pasture was greater than on farms with access to pasture on floors made of mastic asphalt and on slatted concrete floors. However, on rubber floors claw width was smaller on farms with access to pasture than on farms without pasture. On farms without access to pasture the greatest claw width was found on slatted concrete floors and the smallest on rubber floors, whereas on farms with access to pasture claw width was greater on mastic asphalt and rubber floors than on slatted concrete floors (interaction of floor type x access to pasture: $F_{2,\,29}$ = 4.54, P = 0.0193).

Claw shape

Both at the end of the winter and summer period odds for cows with flat soles were increased on mastic asphalt compared to rubber floors even though these odds decreased from winter to summer (Tab. 1). The odds for flat soles did not differ on slatted concrete floors compared to rubber floors and they did not differ on these floors between seasons. In comparison to rubber floors, the proportion of cows with concave claw soles was lower on mastic asphalt and of a similar level on slatted concrete floors (Tab. 1). At the end of the summer period the proportion of cows with concave claw soles was higher than at the end of the winter period on all floor types. Access to pasture did not influence the occurrence of flat or concave claw soles. The proportion of cows with overgrown claw horn at the sole was higher on the hard floor surfaces of mastic asphalt and slatted concrete than on rubber floors (Tab. 1). In the summer period the proportion of cows with overgrown claw horn increased on all floor types.

Discussion

The aim of this study was to determine the influence of floor surface and access to pasture on claw characteristics in dairy cows. In line with Telezhenko et al. (2009) net growth of the claw horn was greatest on rubber flooring and lowest on mastic asphalt. Moreover, our observed effects of solid rubber floors on claw length seem to be similar to those of rubber covered slatted floors (Benz, 2002; Kremer et al., 2007).
Following Toussaint-Raven et al. (1985) who argue that a low net growth of the claw horn may be advantageous for sustaining the claw shape with an intended claw length of about 7.5 cm and a steep claw angle mastic asphalt would seem advantageous for the cows. But even if claw horn growth of cows is positively affected by wear due to the abrasiveness of the floor type (Hahn et al., 1986), we assume that this adaption is only possible to a certain degree and the risk of severe claw damage is high if wear of claw horn exceeds the growth of the claw. Because higher net growth rates of the claw horn were found on slatted concrete and on solid rubber floor which can be attributed to the weaker abrasiveness of the floor, claw trimming will be more often needed for restoring optimal claw length on these floor types.
The increase in claw angle observed during the winter indoor housing period could be due to augmented wear of claw horn at the toe of the claw on mastic asphalt and slatted concrete floors, but claw angle differences increased slightly on rubber floors too. In line with our results, Somers et al. (2005) reported an increase in claw angle during the winter housing period and a more pronounced increase on a hard concrete floor. In contrast, Kremer et al. (2007) found a larger decrease in claw angle on a rubber covered slatted floor than on a slatted concrete floor. In general, an increase of the claw angle is judged positively. Our results, however, show that the influence of the season was more important for the development of claw angle than the type of floor. On mastic asphalt, the decrease in summer was lowest and the increase in winter was highest. It is thus concluded that mastic asphalt is more beneficial for sustaining a steep claw angle than slatted concrete or solid rubber floor or, again, claw trimming may be necessary more frequently on solid rubber and slatted concrete floors.
In agreement with the results of Telezhenko (2007), floor type did not influence the disproportion between the lateral and medial claw. Accordingly, Nuss and Paulus (2006) attributed differences in size between lateral and medial claw mainly to anatomical differences. In our study, claw width varied between the floor types investigated, but the floor effect was different on farms with and without access to pasture. Somers et al. (2005) did not find a difference in claw width recorded during the winter housing period in dairy cows kept on slatted concrete floors, solid concrete floors and straw yard floors. This parameter thus does not currently seem to be important for evaluation of different floor types.
In comparison to rubber flooring, we found more cows with flat soles and the lowest proportion of cows with

concave claw soles on mastic asphalt, both at the end of the winter and the summer period. Similarly, Telezhenko et al. (2009) observed that after restoring the concavity of the sole at claw trimming, a loss of concavity occurred and claw soles became convex even on mastic asphalt.

In our study, the proportions of cows with concave and flat claw soles were on a similar level on slatted concrete and on rubber floors. This is again in accordance with the results of Telezhenko et al. (2009), who found that claw sole concavity of cows kept on slatted concrete floor and on rubber floor did not differ. It seems that abrasiveness of the floor affects both, net claw horn growth and the occurrence of flat or the absence of concave claw soles and thus net growth and shape of sole are correlated. Since cows kept on mastic asphalt have a higher risk for flat soles, slatted concrete and solid rubber floor are preferable, and restoring the concavity of the claw sole on mastic asphalt is of particular importance at claw trimming.

Finally, overgrown sole horn was mainly detected on the hard floor types, i. e. on mastic asphalt and slatted concrete floors in the present study. Van der Tol et al. (2002) showed that the pressure distribution on the claw is not physiological on hard surfaces, resulting in an overgrown sole horn that may cause haemorrhages and bruising. From this point of view, solid rubber floor is beneficial for cows' claws and hard floor types are not to be recommended.

The sample size of our study was quite large but not sufficient to consider all factors that could possibly influence claw characteristics (e.g. floor quality in terms of abrasion) in detail. Such factors may indeed have contributed to the variation observed in our data and this could have masked the effect of floor type. However, variation in these factors is typical for commercial farms and the effects of floor type described in our study are thus likely to reflect the situation to be expected in practice.

Cows on half of the farms in our study had access to pasture during the summer period, allowing an examination of whether outdoor exercise on pasture can mitigate the negative effects of flooring in the indoor walking area on claw characteristics (e.g. stronger net claw horn growth on solid rubber floors, low net claw horn growth and flat claw soles on mastic asphalt). Our results do not support this, as net claw horn growth was not at all influenced by access to pasture and claw angle and claw width only marginally. Access to pasture also had no influence on the proportion of cows with concave or flat claw soles. One reason for this finding could be that time spent on pasture was too short (median 4 h per day) to have a beneficial effect.

The season, i.e. the period before claw trimming, was part of all statistical models, and influenced nearly all the claw characteristics investigated. During the summer period net claw horn growth was on a higher level than during the winter period. Claw angle differences were smaller in the summer period and negative (claw angles became shallower), whereas these differences were positive in the winter period (claw angle increased). Somers et al. (2005) also reported an increase in claw angle in cows during the winter housing period, and Hahn et al. (1986) found higher growth rates and shallower claw angles in dairy cows kept on pasture during the summer period. After the summer period the proportion of cows with concave claw soles was higher in the present study, but the proportion of cows with overgrown soles increased too. This could be linked to generally higher claw horn growth during the summer due to changed feed composition.

In summary, none of the investigated floor types was clearly superior to the others with regard to claw dimensions and claw shape. With regard to claw characteristics, the adjustment of claw trimming strategies to the flooring is of particular interest: On mastic asphalt, claw trimming should focus on restoring concavity of the claw sole and examination of the claw should be targeted on indicators for excessive floor abrasiveness. On slatted concrete and on rubber floor, claw trimming should focus on restoring an optimal claw shape (adequate claw length and angle, concave claw sole). Access to pasture during summer (median 4 h per day) had only a slight influence on the claw characteristics investigated. Thus, our hypothesis that pasture could mitigate the negative effects of floor type in the indoor walking area was not corroborated.

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Influence du sol et de la mise au pâturage sur la dimension et la forme des onglons de vaches laitières détenues en stabulation libre à logettes

Cette étude avait pour but de déterminer l'influence du sol dans la zone de sortie ainsi que celle de la mise au pâturage sur les dimensions et la forme des onglons de vaches laitières. Le recueil des données s'est

Influenza del pavimento e dell'accesso al pascolo sulle dimensioni e la forma dell'unghione nelle mucche da latte in stalle a stabulazione libera con box

Scopo dello studio era di determinare l'influenza del pavimento nelle corsie e dell'accesso al pascolo sulle dimensioni degli unghioni e la loro forma nelle mucche da latte. La raccolta dei dati ha avuto luogo in 36 fait dans 36 exploitations avec une stabulation libre à logettes, 12 avec une zone de sortie en asphalte,12 en béton et 12 recouverte de matelas de caoutchouc fixés. Indépendamment de la qualité du sol, les vaches avaient, sur la moitié des exploitations, accès au pâturage durant l'été. On a recueilli sur chaque exploitation des données sur 10 vaches à trois reprises, avec un intervalle d'environ 6 mois. La croissance des onglons était maximale sur les sols en caoutchouc et minimale sur l'asphalte. Quel que soit le type de sol, l'angle de la paroi était plus grand à la fin de la période hivernale et plus petit à la fin de l'été. Le type de sol avait aussi une influence sur l'apparition d'onglons plats, concaves ou trop longs. Dans l'ensemble toutefois, aucun des types de sol ne se révélait nettement supérieur et la mise au pâturage (en moyenne 4 heures par jour) n'avait qu'une faible influence sur les dimensions et la taille des onglons.

allevamenti con stalla a stabulazione libera con box, 12 dei quali avevano corsie di asfalto colato, grigliate in calcestruzzo o tappeti di gomma fissati. Per ogni tipo di pavimento, le mucche avevano accesso al pascolo d'estate su metà dell'azienda. Per ogni azienda si sono raccolti i dati in 3 momenti differenti a distanza di circa 6 mesi ciascuno su 10 mucche. La crescita degli unghioni era avvenuta maggiormente sul pavimento in gomma e poco sull'asfalto colato. Indipendentemente dal tipo di pavimento, l'angolo tra gli unghioni, alla fine del periodo invernale, era maggiore e alla fine del periodo estivo minore. Il tipo di pavimento ha avuto anche un'influenza sulla comparsa di unghioni piatti, concavi e cresciuti in eccesso. Nel complesso, nessun tipo di pavimento si è rivelato chiaramente vantaggioso e l'accesso al pascolo (in media di 4 ore al giorno) a avuto solo uno scarso effetto sulle dimensioni e la forma degli unghioni.

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