Benz, Barbara; Barsch, Tanja; Hubert, Sabine and Richter, Thomas

The influence of elastic rubber mats in a milking parlour on claw dimensions of dairy cows

Hoof diseases and disorders are a big animal welfare problem in dairy herds and one of the most common cause of losses on German dairy cattle farms. Any deviation from the correct claw shape may lead to unphysiological loading and as a consequence of this to hoof diseases. The present study compares the claw shape of German Simmental Cows in a stable before and after the installation of elastic rubber mats in a steep herringbone parlour. In the beginning there existed an abrasive soil and the height of the bulb was too low in 87% of cows. Four months after the installation of the mats, 77% of the cows had bulb heights within the reference range. No differences between claw measurements were found depending on milk yield and number of lactation. The results of this study indicated that the flooring surface in a milking parlour had a significant influence on claw shape.

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Abstract
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Hooves and legs of cows are especially subject to stresses when animals are housed year-round. Hereby, hooves represent the weakest link [1] supporting, as they do, the cow's entire weight on the ground. In order to carry this load, hooves must retain an optimal form [2].

Based on the rear hooves of 40 slaughter cows, Nuss and Paulus established reference or target values for hoof size with Simmental cows [3]. Hereby, the hooves were first of all pared to give a defined sole thickness of 5 mm at the claw points and 8 mm in the bulb area. Subsequently the dorsal wall length, dorsal wall angle, bulb height and breadth, hoof length, length and breadth of the sole, as well as the sole area, were all measured. The measurement procedure was developed by Nuss and Paulus in a previous study [3] and applied in the research reported here. Measurements given for the dorsal wall length of hooves with young cows up to 36 months of age were 7.56 and 7.63 cm, for older cows over 36 months 7.78 to 7.80 cm. The reference value for the dorsal wall angle lay between 48.2 and 51.4° [3]. The reference values were taken from another study for the dorsal wall angle of fattening bulls [4] and the bulb height of young and older cows. The dorsal wall angle for fattening bulls was given as from 55.8 to 57.8°. The bulb height for young cows lay between 2.88 and 3.36 cm. With older cows, the range was greater and lay between 2.65 to 3.41 cm.

An as large as possible bulb height is recognised as an effective protection against infectious disorders of the bulb area. Through the long-term effect of dung and urine contact, damage and softening of the skin in the bulb area takes place. This increases predisposition to Dermatitis digitalis and heel horn rot [5, 6].

With physiologically formed hooves, the main part of bodyweight is carried by the hoof walls where they meet the ground and the sole has only a support function [1]. Where this hoof structure changes, overloading of the deeper lying, more sensitive, structures in the sole area can take place. This leads to blood circulation problems and poor supply to the horn building structures and thus to an adverse influence on horn development [2]. Negative effects on horn development result in an altered structure and quality of the horn. The horn quality is characterised by Mülling et al. based on horn cell architecture as well as intracellular and intercellular factors [7]. Poor quality horn can only to a limited extent fulfil its function as protection from mechanical, chemical and bacterial influences [8; 9].

Through sole horn desquamation in nature-near animal management systems on pasture or on flooring covered with elastic rubber matting, the load-bearing rim of the hoof protrudes below the sole level. Just as where the hoof sinks into softer ground under pressure, the sole thus carries some of the weight [10]. Where hooves are pared according to the requirements of functional hoof trimming, a flat sole area is produced so that the large weight is distributed over as big a surface area as possible on both hoof halves. If, in addition, the load bearing hoof rim is worn down until it is under the sole level, the pressure stresses on cow hooves can no longer be converted for a tensile loading [1]. Hard and rough ground wears down the load-carrying horn rim quickly, leading to a flat or rounded load-carrying edge form, so that the entire sole area is in contact with the ground. An inspection of six farms with year-round loose-housed cattle showed that, following fitting of passageway matting, 95.5% of the animals had a protruding load-carrying hoof rim whereas, before beginning of the trial, only 74.8% of the animals were observed with a clear round load-bearing rim [11].Based on these results, Reubold assessed the form of the load-bearing rim as suitable parameter for assessing passageway construction.

The aim of this study was to test the effect of elastic rubber matting in a farm with steep herringbone milking parlour. With the cows involved, hoof condition was compared using reference values, before and after the fitting of matting. Furthermore, the results were analysed for any relationship to milk production level and lactation number. Only a weak relationship was found to exist between milk production performance and hoof disorders [12]. Because of the altered feeding activity of cows with different milk production levels and lactation numbers [13] any possible interaction between these factors and hoof form was analysed.

Materials and methods

The investigation was conducted on a dairy farm in Göppingen district where 121 Simmental cows are housed in a three-row deep-bedded cubicle barn with solid concrete passages and a steep 80° herringbone 16 x 16 milking parlour, all built in 2009. The 50 m^2 parlour had an epoxy resin floor coating. The sliding friction coefficient of the parlour floor and in the cubicle barn was measured with the mobile "ComfortControl Test Stand" from the DLG Test Centre Technology and Farm Inputs [14]. In the test, a load-bearing plastic foot (test weight 10 kg) is pulled over the flooring or floor covering at constant speed (20 mm/s). From the required pulling power registered, the sliding friction coefficient μ is calculated. The minimum value giving reliable foothold is 0.45 μ. The sliding friction coefficient of the barn passageway flooring lay, however, at only between $\mu = 0.30$ and $\mu = 0.35$. The sliding friction coefficient of the parlour floor was $\mu = 0.40$.

At the end of April 2013 the parlour floor was fitted with elastic rubber matting (**Figure 1**). The rubber mats (KURA Form, Gummiwerk Kraiburg Elastik GmbH & Co KG) were 24 mm thick, with 5 mm high studs on the underside and, when dry, returned a sliding friction coefficient of $\mu = 0.61$.

Fig. 1

Fig. 1: Elastic flooring in the herringbone parlour with fast exit (Photo: B. Benz)

At four-month intervals, the farmer treated all cow hooves employing a professional team following functional hoof trimming principles [10]. As part of this routine, the hooves of all the cows were measured before treatment.

Following the Paulus procedure [5], the dorsal wall length, the bulb height, the dorsal wall angle and the sole profile were all measured. The dorsal wall length was defined as the distance between the hairline where skin meets hoof and claw points. This was measured by sliding calliper featuring ± 0.5 mm scale with measurement length of 150 mm, finger length of 40 mm and a scaling of 0.05 mm (**Figure 2**, b). The bulb height was measured vertically from the border of the haired skin at the coronary band down to the end of the horn shoe on the ground. Hereby, a metre stick was used to measure the middle of the bulb breadth. The dorsal wall angle was determined by the angle of inclination of the dorsal wall to the sole surface using an electronic inclination sensor (360° inclination sensor Level Box) (**Figure 2**, c). This had a measurement scope of ±180° and a precision of 0.1°.For measurement of sole profile – based on Telezhenko et al. [15] – a contour gauge with a breadth of 130 mm and depth of 50 mm was placed at the broadest point of the sole (**Figure 2**, a).The profile thus depicted was transferred onto millimetre paper after conclusion of the measurements. The form of the load-bearing rim was divided between the categories "rounded-off" and "not rounded-off". A rounding-off meant that the load-bearing rim lay under the level of the sole area.

The hooves were measured on December 2012, on April 2013 before the fitting of the rubber matting and on August 2013 four months after the fitting. All 121 cows had their right rear hoof measured. Through culling, drying off and interim treatments of hooves data was not available for all the cows for the entire investigation period. Thus only 31 animals with complete records from all three measurement dates were analysed. These animals had a 305 day lactation production of 8031 kg milk at 4.10% fat and 3.82% protein. 13 cows were in the first or second lactation (young cows) and 18 in the third to fifth lactation (older cows). The average lactation number was therefore 2.9.

Fig. 2

a) *Measurement of the sole profile* (Photos: B. Benz) b) *Measurement of the dorsal wall length* c) *Measurement of the dorsal wall angle*

Statistics

Firstly, the absolute values of the hoof measurements from the "before period" and the "after period" were tested for normal distribution and homogeneity. Then, the dependent variables bulb height, dorsal wall angle and dorsal wall length (in each case medial and lateral) were tested for with a T-test with linked sampling for significant differences regarding the factor time ($p \leq 0.05$). The influence of milk production performance on hoof measurement differences between "before period" and "after period" was tested for significance with a bivariate correlation according to Pearson. To establish whether the number of lactations had an influence on the hoof measurement changes, a variance analysis was carried out by which the lactation number was defined as a factor and the changes in hoof measurement defined as a dependent variable (F-test, $p \leq 0.05$). All data were distributed normally (KS-test, $p \leq 0.05$), the variances homogenous (Levene-test, $p \leq 0.05$). For the difference between "before period" and "after period" the measurements of mass at starting condition were subtracted from those of the end condition. A difference with a positive fore-symbol therefore meant growth had taken place, a negative one, on the other hand, meant wear/reduction of the hoof cross section had occurred. In order to test for a relationship between milk production performance and changes in hoof measurements (difference), bivariate correlations according to Pearson ($p \leq 0.05$) were calculated.

Results and discussion

Comparison of the measured hoof parameters with the reference values showed that the hooves in their starting condition had low bulb heights and steep dorsal wall angles that were nearer the values for fattening bulls than for cows (**Table 1**).

Hoof dimensions after fitting the rubber matting

Within the four months following fitting of the elastic floor covering in the milking parlour the bulb height increased signifi-

Table 1

Comparison of the claw measurements with reference values [3; 4; 5]

Parameter/*Parameter*		Dorsalwandlänge/*Dorsal wall length* (medial/lateral) [cm]	Trachtenhöhe *Bulb height* [cm]	Dorsalwandwinkel *Dorsal wall angle* [Grad]/*[Degree]*
Referenz/*Reference*				
Jungkühe/*Young cows*		7,56/7,63	2,88–3,36	48,2–51,4
Altkühe > 36 Monate/*Old cows > 36 months*		7,78/7,80	2,65–3,41	
Mastbullen/*Fattening bulls*		7,28/7,37	1,95–2,35	55,8–57,8
Eigene Untersuchung/*Own investigation*				
Total N = 31	Mittelwert/*Mean*	8,3	2,4	57,2
	SD	0,7	0,5	0,5
Jungkühe/*Young cows* N = 13	Mittelwert/*Mean*	8,1	2,4	57,1
	SD	0,8	0,2	0,8
Altkühe/*Old cows* N = 18	Mittelwert/*Mean*	8,4	2,4	57,4
	SD	0,6	0,6	0,6

cantly from 2.4 to 3.1 cm and achieved the targeted reference area. The parameter bulb height had – as already shown – an importance for the physiological load as well as for the predisposition of skin diseases such as Dermatitis digitalis and bulb horn rot. The higher the bulb is, the greater the distance from the dirty barn floor. The dorsal wall angle became significantly smaller for the lateral, and as well as for the medial, claw. In the "before period" the dorsal wall angle was tendencially too steep which can lead to a more pronounced loading of the claw points. Dorsal wall angles of 56 to 58° are more characteristic for fattening bulls. From investigations of fattening bull hooves it is known that, in such cases, so-called inner shoe defects (ISD) often occur. These are assumed to be painful, although only first identifiable through post mortem investigation [16]. Reduced dorsal wall angles nearer to the reference values of cows were measured on the hooves of the inspected animals. With the dorsal wall length no alterations between the "before" and "after" periods were found. In both investigation periods, the values lay a few millimetres over the reference values. The variation coefficient of the hoof dimensions showed, apart from the bulb height, comparatively limited distribution between the individual animals (**Table 2**).

Figure 3 shows how the hoof form in total neared that of the reference values following fitting of the milking parlour matting. Especially marked is the change in bulb height. The "after period" lasted only four months. It would be interesting to investigate whether the changes would be even more marked over a longer observation period.

Before the beginning of the investigation, hooves of all the cows were already regularly cared for thrice yearly by the same person. In that the hoof parameters within the framework of the study presented here were measured before the hoof care routine, the last hoof care operation lay four months beforehand for all the three dates. From this, it could be assumed that the hoof care had no significant influence on the recorded hoof parameters and that the changes that occurred can be attributed to the influence of the milking parlour matting.

Changes in the load-bearing hoof rim

The developments of the weight-bearing rim were analysed through sole profile measurement. In the "before period" 59 % of the animals had a rounded-off load bearing hoof rim. Four months after the fitting of the rubber matting, rounded-off load bearing rims could only be identified with 10 animals (34 %). Because the load-bearing rim has an important function in load transference, a load-bearing rim that is "rounded off" under the sole level can be judged as critical. In the normal gait of the cow there is hardly any wear to the side area of the load-bearing rim. From that, it may be assumed that it is turning movements that cause above-normal wear with the load-bearing rim. Such turning movements are not only carried out by cows entering or exiting a steep herringbone milking parlour but also in barn movement areas in the vicinity of drinking troughs, automatic concentrate feeders and at the feed railing. Apparently, however, the flooring in the milking parlour of the trial farm had a particularly pronounced influence on the bearing rims of the hooves. The finding "rounded-off bearing rim" was reduced by almost 60 %.

Influence of milk production level and lactation number

From a previous investigation it was known that cows, depending on milk production level and number of lactation, display different behaviour during feeding [13]. Animals with lower milk production and young cows (first and second lactations) participated more often in feeding periods and actual feeds. In that they therefore visited the feeding place, or changed

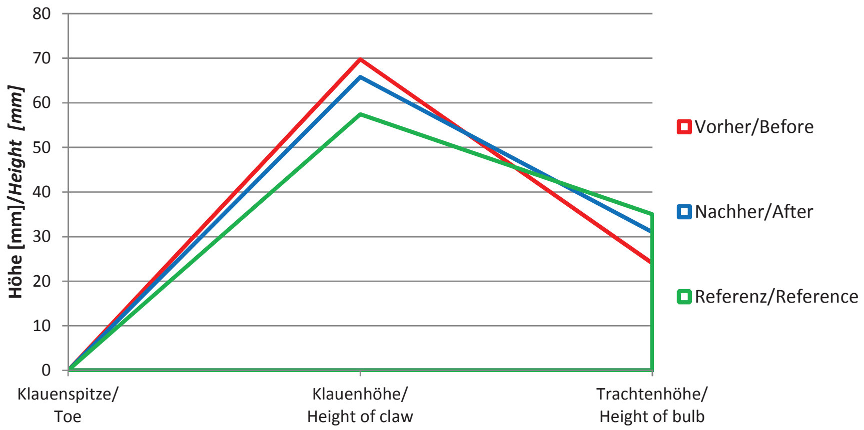
Table 2

Claw measurements in the "before period" and "after period" (t-test)

Parameter *Parameter*	Zeitraum *Period*	Einheit *Unit*	Mittelwert *Mean*	SD[1)]	VK[2)]	p-Wert *P-level*	Signifikanz[3)] *Significance*
Trachtenhöhe *Height of bulb*	vorher/*before*	cm	2,4	0,4	0,17	0,000	***
	nachher/*after*		3,1	0,6	0,19		
Dorsalwandwinkel lateral *Lateral dorsal wall angle*	vorher/*before*	Grad *degree*	58,2	3,7	0,06	0,014	*
	nachher/*after*		56,1	4,8	0,09		
Dorsalwandwinkel medial *Medial dorsal wall angle*	vorher/*before*	Grad *degree*	56,4	3,3	0,06	0,000	***
	nachher/*after*		52,4	4,7	0,09		
Dorsalwandlänge lateral *Lateral dorsal wall length*	vorher/*before*	cm	8,7	0,8	0,09	0,535	n.s.
	nachher/*after*		8,6	0,9	0,10		
Dorsalwandlänge medial *Medial dorsal wall length*	vorher/*before*	cm	7,8	0,8	0,10	0,288	n.s.
	nachher/*after*		7,7	0,6	0,08		

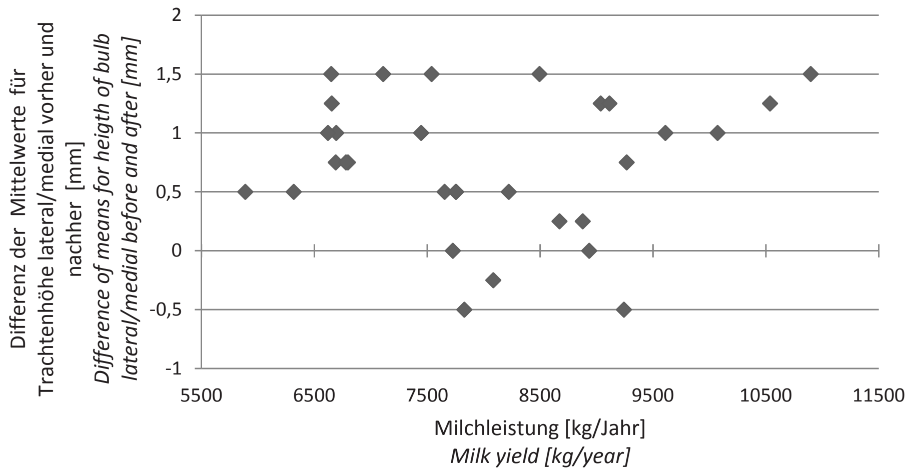
1) SD: Standardabweichung/*Standard deviation*
2) VK: Variationskoeffizient/*variation coefficient*
3) Signifikanz/*Significance*: p < 0,05 signifikant/*significant* *, p < 0,01 sehr signifikant/*very significant* **, p < 0,001 höchst significant/*most significant* ***, p > 0,05 nicht signifikant n.s. /*not significant*

Fig. 3



Development of claw shape during the investigation period (mean values)

Fig. 4



Spread of bulb height differences „before“ and „after“ depending on milk yield

feeding places, more often, the influence of increased use of the movement apparatus on the balance of horn building and wear, and thereby on hoof form, could occur. Because of this, a possible influence from milk production level and lactation number was investigated. The parameter milk performance showed no correlation to any of the hoof parameters. In addition, the lactation number had no significant influence on the differences of the hoof dimensions (F-test, $p \leq 0.05$). **Figure 4** demonstrates the distribution of the differences of bulb height in the ”before“ and ”after“ periods in relationship to milk production performance.

Conclusions

A physiological hoof shape is important for correct load bearing relationships. Especially for prevention of infectious hoof disorders an as large as possible bulb height should be aimed for in order to give as great a distance as possible between the susceptible bulb area and the mainly dirty movement area surfaces. On the trial farm the hoof form of the cows before fitting the rubber matting in the milking parlour with regard to parameters bulb height and dorsal wall angle showed marked deviations from the reference values. After the fitting of the elastic matting in the milking parlour, significant changes were able to be measured right through to a correct hoof shape. The lactation number had no influence on hoof shape deviations and no correlation was found between milk production performance to any of the parameters. Thus, the floor covering in the milking parlour had a marked influence on the hoof shape of the cow, whereby different activities of the animals on other movement surfaces in the trial farm played a subsidiary role.

The special situation with the trial farm lay in the very steep design of the herringbone milking parlour (80°) which led, with cow entry and exit, to obvious pronounced turning movements of the hooves on the ground surface. Although the existing epoxy resin floor covering achieved an almost optimal coefficiency of friction, the hoof friction in the area of the bulb was still apparently too high. In that it can be assumed from this that a physiological hoof shape supports hoof health, the fitting of an elastic flooring cover in the milking parlour – to the background of continued hoof problems in many dairy farms – could offer an interesting method for helping improve hoof health. Similar types of milking parlours e. g. side-by-side parlours, are no exceptions in this case and they, too, are increasingly used. For this reason, the results of the investigation presented here could be of interest on commercial farms regarding the type of flooring in the respective milking parlours.

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Authors

Prof. Dr. Barbara Benz is professor for animal production, **B. Sc. Tanja Barsch** studied agricultural economics and **Prof. Dr. met. vet. Thomas Richter** is professor for animal production at the HfWU - Nürtingen-Geislingen University, Neckarsteige 6–10, 72622 Nürtingen, E-Mail: barbara.benz@hfwu.de

Sabine Hubert, Dipl. agr. Ing. (FH) is scientific assistant for plant production and phytomedicine.

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