Claw Disorders and Disturbed Locomotion in Dairy Cows: the Effect of Floor Systems and Implications for Animal Welfare

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Claw Disorders and Disturbed Locomotion in Dairy Cows: the Effect of Floor Systems and Implications for Animal Welfare

Klauwaandoeningen en gestoorde locomotie bij melkkoeien:
de invloed van vloersystemen en implicaties voor dierwelzijn

(met een samenvatting in het Nederlands)

Proefschrift

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door

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geboren op 12 oktober 1974 te Vorstenbosch

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LIVE**YELLOW.** LIVE**STRONG.**

Voorwoord

Het boekje is zo goed als klaar. Na duizenden klauwen, locomotiefilmpjes, km's in de auto, sasfiles, een paar venijnige koeientrappen, een illusie armer en een ervaring rijker, maar vooral véél werkplezier is de klus geklaard. Tijd om een aantal mensen de revue te laten passeren die hebben bijgedragen tot wat het proefschrift geworden is. Jullie allen bedankt!

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Dörte; jouw Mortellaro foto's zijn onmisbaar geweest bij het correct diagnosticeren van M1, M2, M3 en M4 stadia.

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Joan Somers
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Contents

Chapter 1

General Introduction

INTRODUCTION

In modern dairy housing, flooring conditions lead to restricted locomotion and claw disorders. Lameness and claw disorders constitute a significant health and welfare problem in modern dairy farming. Until the early nineties, claw and locomotor disorders were mainly considered an economic issue. Financial losses due to poor claw and locomotor health were estimated to alert dairy farmers to the seriousness of this type of problems (Whitaker et al., 1983; Harris et al., 1988; Tranter et al., 1993). Lameness was ranked third in losses from dairy diseases, following mastitis and fertility problems (Baggot, 1982). Later, a shift in view was seen towards concern about compromised animal welfare. The change in vision was closely connected to the rising politic and public debate about intensive livestock production and its detrimental effect on animal well-being (e.g, RDA, 1996; FAWC, 1997). Furthermore, in line with guidelines for food safety and public health, the European Commission has issued policies on health and welfare of production animals (EC-regulation 178-2002). This regulation requires farmers to identify the herd's health and welfare status by means of Good-Manufacturing-like codes.

In reaction to the growing concern about the quality of life of production animals, The Netherlands Organisation for Scientific Research (NWO) initiated in co-operation with the Ministry of Agriculture, Nature and Food Quality a Priority Program called 'Limits to Animal Welfare and Production'. Scientists were called to identify and find solutions for important welfare problems in livestock but also to provide tools for welfare assessment of animal production systems. The research presented in this thesis derives from that NWO program. The next section of this chapter gives an outline of some characteristics of modern dairy farming. Next, claw and locomotion disorders associated with dairy production will be described as well as general conditions contributing to those problems. Finally, the content and the main research questions of this thesis are presented and an overview is given of the approach followed to address them.

MODERN DAIRY FARMING

The introduction of loose housing for dairy cattle in the seventies and early eighties is considered as a radical change in dairy farming. Up to then, dairy cows were mainly kept in tie stalls. The new design of dairy housing comprises one location where all cows are milked (i.e. milking parlour), a separate area with the required equipment for feeding the cows, and a resting area furnished with individual lying places (i.e. cubicles). The areas are usually connected by concrete passageways. This type of housing credited for far-reaching possibilities of labour saving. Efficacy of the milking process was highly improved, resulting in less labour per cow and better working conditions (Dodd and Hall, 1992). As a result, larger herds were manageable by one person, also facilitated by increased automation at the farm. Dairy farming in The Netherlands has substantially intensified from then onward: the number of cows per farm has increased over 75% between 1980 and 2003 (Agriculture Statistics 2003; www.cbs.nl). Dutch dairies are rated nowadays third within Europe following United Kingdom and Denmark with regard to average herd size (56 dairy cows) and average herd production (0.4 million kg year^{-1}) (Anonymous, 2003). At the same time, cow production has increased considerably: present cow yield average 8700 kg milk per lactation versus 5450 kg in 1980 (NRS, 2002). Besides the change to loose housing, improvement of feeding strategies and selection on production traits, with a shift from Dutch-Friesian to Holstein-Friesian, have contributed to that strong rise in cow and herd performance. For animals, an important benefit of loose-housing is that they are able to move around in their housing environment. Gustafson (1993) demonstrated that movement has a positive effect on animal health: exercised-cows that walked between 0.5 and 2 km daily, were less affected by mastitis, leg problems, and calving-diseases than non-exercised cows (constantly tied). Besides free movement, loose-housed cows have social contact with each other. Both conditions contribute to the well-being of animals (Webster, 1995).

About 80% of the 1.5 million dairy cows in The Netherlands are housed nowadays in cubicle houses (according to the Agriculture Statistics 2000; www.cbs.nl). Apart from the common characteristics, it is essential to point to the variation in floor types. Construction of the walking surfaces varies among this loose-housing type with the slatted concrete floor being the dominant floor system (over 90%; www.cbs.nl). Faeces and urine excreted by animals drain along the longitudinal slots into a slurry pit below. To ensure better cleaning of the floor, slatted floors are increasingly equipped with a manure scraper. In some areas in The Netherlands complete underfloor storage of slurry is not practicable and rather costly due to poor soil conditions. Then, an alternative is a solid concrete floor (installed in about 7% of all cubicle houses; www.cbs.nl), which is automatically scraped several times a day, and slurry is moved to an outside storage. In the mid nineties, low-ammonia emission floor systems were introduced in response to environmental protection policies of the Dutch government. Two variants were developed: a sloped and a grooved floor (Braam et al., 1997). The characteristic design of both floors enabled a better drainage of urine while the underlying manure pit was no longer an open storage, resulting in ~ 50% lower ammonia emission. However, because of extra construction costs, limited renovations of existing floors, a small amount of new dairy houses each year, and changing environmental policy of the government, such low-emission floors are introduced at small scale so far. Currently, the grooved floor is the most common low-emission floor in practice (the sloped floor was too slippery for the cows to be kept on). Besides the intense use of cubicle houses, a small percentage of dairy cows (less than 1%) are housed in straw yards. This loose-housing system has a deep litter area where animals can rest collectively by lying on straw bedding. Generally, this system has a concrete walking surface in front of the feed alley. Despite the lower building costs, the straw yard is not a common housing facility for dairy cattle. This might be due to associated labour increase and deteriorated udder health (Fregonesi and Leaver, 2001).

Dairy cows in The Netherlands are usually housed from October to May and are at pasture during the late spring and summer. On the other hand, it becomes more and more practice to pasture cows only during daytime for economic and management reasons. In 2001, 54% of the dairy cows in The Netherlands stayed indoors at night during the pasture season. Additionally, an increasing number of animals stay indoors during daytime as well, a production system known as zero-grazing. In 2001, one tenth of the dairy cow population in our country 'summered' indoors instead of at pasture (*www.cbs.nl*) and this number will most likely increase in the coming years due to economic and practical reasons. A poll conducted among farmers identified labour control, stringent manure legislation, and better fulfilment of nutritional demands in high-yielding cows as most important motives to apply zero-grazing (especially in larger herds; above 100 cows) (Anonymous, 2002).

The differences in livestock systems - specifically the housing conditions and floor types cows have to deal with – are relevant for the locomotor functions of dairy cows in two respects: it determines the need for free and unrestricted locomotion in the production system, and at the same time it determines how strong the locomotor functions are at risk due to negative impact of environmental factors, causing disturbed locomotion and claw disorders.

LOCOMOTOR PROBLEMS AND CLAW DISORDERS

Dairy cows require unrestrained mobility to express normal behaviour and meet their biological demands. A safe, comfortable floor surface and a healthy locomotor apparatus (and thus healthy claws) are essential conditions to perform normal locomotion. Existing loose-housing systems, however, are a major cause in the high frequency of disturbed locomotion and claw disorders in dairy herds (e.g. Leonard et al., 1994; Philipot et al., 1994b; Faull et al., 1996; Manske, 2002). A typical feature of loose housing is the concrete walking surface. Concrete is a hard underground that hardly deforms under loading, resulting in high mechanical pressures applied to the bovine claw while standing or walking (Scott, 1988; Van der Tol et al., 2003), causing restricted locomotion and increased risk for claw disorders (Bergsten and Frank, 1996; Van der Tol, 2004). Another aspect is floor hygiene. Claws of loose-housed cows are largely exposed to manure excreted in the alleys. Wetness is detrimental to the claw capsule (Mülling and Budras, 2002) and predisposes for certain claw disorders (Blowey and Sharp, 1988; Frankena et al., 1993). Also excreta from other cows may be a source of infection (Bergsten and Pettersson, 1992). Cows at pasture (Peterse, 1985; Faye and Lescourret, 1989; Frankena et al., 1991) and tied-cows (Maton, 1987; Hultgren, 2002) show less and less-severe claw lesions than loose-housed cows, probably because of drier foot circumstances, lower infection pressure, and a mechanical-buffing underground.

Claw disorders can be categorised based on their origin into infectious and traumatic/metabolic lesions. The first usually affect the skin surrounding the claw capsule and the interdigital space (interdigital dermatitis, digital dermatitis, interdigital phlegmon and resulting interdigital hyperplasia), while the latter affect the sole of the claw (sole ulceration, white line disease, sole haemorrhage). Several detailed studies investigating claw lesions in dairy cattle have been conducted over the past decades. Estimations of percentages of affected animals are fairly high throughout this time. In 1972, Prentice and Neal found that three-quarters of the British cattle showed lesions at claw trimming. Some years later, a prevalence of 80% was reported in Switzerland (Martig et al., 1979). In the early nineties, two large studies among Dutch cows pointed out that the majority of the animals (~ 95%) were affected by at least one disorder (Frankena et al., 1991; Smits et al., 1992). A French survey also indicated that about 90% of the animals had claw lesions at one time (Philipot et al., 1994a). In all studies only hind claws were examined because 85 to 90% of all claw lesions occur at the hind feet, primarily on the lateral digit.

In literature, the term ‘subclinical’ lameness is sometimes used when referring to claw lesions (e.g. Alban, 1995; Vaarst et al., 1998). The term implies that the disorder(s) cannot be identified by looking at animals’ locomotion, but only when feet are lifted. ‘Not visually lame’ does not imply that an affected animal does not suffer from a claw disorder. However, if claw lesions do lead to lameness, suffering is visually manifested. In that case the well being of an animal is clearly impaired. A lame cow suffers from pain while moving or loading the affected limb. The following reduction in mobility interferes with normal behaviour (Singh et al., 1993; Galindo and Broom, 2002). Food and water intake and other behavioural functions may be impaired, which can be a relevant source of reduced well-being, that should not be undervalued (Metz and Bracke, 2003). The annual incidence of lame cows in The Netherlands has been assessed at about 25% (Barkema et al., 1994; Enting et al., 1997). These numbers are in line with estimations from dairy cattle in other countries (Booth, 1989; Whitaker et al., 1983; 2000; Whay et al., 2002), but also incidence rates up to 40 to 55 cases per 100 cows per year have been reported (Clarkson et al., 1996; Kossaibati and Esslemont, 2000).

Claw disorders and resulting lameness have a multifactorial background. Both phenomena are attributed to cow and environmental characteristics of which parity and housing are most highly related, but nutrition, season, management, and genetics are also significant (reviewed by Hirst et al., 2002). Despite knowledge on contributory conditions, a significant reduction in the incidence of claw disorders is not effected so far (e.g. Whay et al., 2002). Solutions to the problem become even more desirable as scientists revealed that farmers greatly underestimate the levels of lameness within their herds. In some studies, herdsmen only recognised 25 to 40% of the actual lame cows diagnosed by trained observers (Wells et al., 1993; Mill and Ward, 1994; Whay et al., 2002). Under-diagnosing may be either the result of lack of suitable conditions for observing cows' gait or unawareness of locomotion disturbances. The consequence, however, is that appropriate treatment is delayed or neglected and affected cows suffer from lameness for a longer period of time. Early diagnosis and treatment of 'subclinical' lameness is of importance to prevent progress into clinical lameness. Heel erosion, for instance, becomes worse during housing and may ultimately cause sole ulceration (and thus pain and acute lameness) (Greenough and Weaver, 1997).

AIM OF THE RESEARCH

Starting point of the research in this thesis is concern about animal welfare in dairy production related to locomotor disorders. Impaired locomotion and lameness are considered major problems that have probably the greatest adverse effect on cow well-being (Webster, 1995). 'Freedom of movement' and 'freedom from pain' are two out of the five freedoms that are required for optimal animal welfare (FAWC, 1992). Both freedoms are unarguably threatened by disturbed locomotion since it causes pain and discomfort. The affected cows are likely to be restricted in their movement and fulfilment of their individual needs. Roughly 90% of all locomotor problems are caused by claw disorders (Weaver, 2000). Therefore, type and severity of claw lesions also are important determinants of manifestation of a locomotor disturbance. This may range from insecure standing and walking, susceptible and painful gait, to obvious lame ('walking on three limbs'). Additionally, the condition may be enhanced by floor characteristics. It has been shown that wet and slippery floors provoke adaptive locomotor behaviour due to the lack of sufficient traction (Phillips and Morris, 2000; 2001).

Epidemiological approaches were used to establish the frequency and determinants of lameness for many years. There is substantial evidence that housing environment and floors in particular are important factors involved in the aetiology of claw and locomotor disorders. However, the problem has not been studied intensively from an ethological perspective in combination with epidemiology. Hence, a multidisciplinary project, described in this thesis, was initiated to investigate epidemiological and ethological aspects of claw disorders and impaired locomotion with special emphasises on floor type and other housing factors. The additive value of this combination lies in the fact that the complex of claw disorders, locomotion, behavioural activity, and housing conditions can be studied simultaneously in the same groups of animals. More precisely, the main objectives of the present work were:

(1) to quantify claw disorders and disturbed locomotion in dairy cows kept on different floor types;

(2) to study the epidemiological background of claw and locomotor disorders, with special interest in housing, flooring, and management factors;

(3) to study the effect of claw disorders on locomotion and other behaviour, in order to quantify their impact on welfare of the dairy cows.

OUTLINE OF THE THESIS

The first step in the research was to gain information on the current claw health status of dairy cows in The Netherlands. A large-scale epidemiological cross-sectional study was conducted to assess the presence and severeness of claw disorders (**Chapter 2**). Floor environment is hypothesised an import factor in the development of diseased claws, and therefore prevalences will be compared between animals kept on various floor systems: on slatted floors, slatted floors with manure scraper, solid concrete floors, or in straw yards. **Chapter 3 and 4** deal with risk-factor analyses for two common infectious disorders, i.e. digital dermatitis (DD) and interdigital dermatitis/heel erosion (IDHE), respectively. Multivariable analyses using logistic regression were used to investigate risk indicators for both disorders at cow- and herd-level in the dairy population described in Chapter 2.

Chapters 5 to 7 describe the results of a longitudinal study focusing on claw traits, claw disorders, locomotor performance, animal behaviour, and their interrelations using animals from commercial dairies. Housing facilities differed with regard to type of flooring (slatted concrete, solid concrete, grooved concrete, and straw yard system) and farms were selected in such a way that each flooring-type group contained three herds. Changes in claw shape over time were studied and are presented in **Chapter 5**. Simultaneously, the relationship between claw traits such as horn growth and wear and horn hardness, and type of flooring was analysed. The chapter also includes an in-depth monitoring of the development of the disorders IDHE and DD.

Chapter 6 and 7 focus on welfare implications of claw and locomotion problems. **Chapter 6** describes to what extent common infectious disorders as DD and IDHE affect normal walking ability. Therefore, gait of animals was evaluated monthly over a 1-yr period by means of an objective locomotion scoring system. Subsequently, individual scores for locomotion were linked with associated cow data on DD and IDHE status (as described in Chapter 5). In **Chapter 7** behavioural changes due to claw disorders and impaired cow mobility are investigated. The relation between daily cow activities represented by 24-hr time budgets and severity of DD and disturbed locomotion was analysed. Furthermore, time budgets were compared between normal and lame cows in cubicle houses, and normal cows in a straw yard.

Finally, main results of the work are evaluated and discussed in the perspective of prevention measures for claw and locomotor disorders (**Chapter 8**).

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Chapter 2

Prevalence of Claw Disorders in Dutch Dairy Cows Exposed to Several Floor Systems

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ABSTRACT

Claw health was examined in an observational study on Dutch dairy farms with either a slatted floor (SL), slatted floor with manure scraper (SL-SCR), solid concrete floor (SCF), a straw yard (SY), or a zero-grazing feeding system (ZG). Hooves of cows' hind legs were examined for the presence and severity of claw disorders during hoof trimming events at the end of the pasture (P-study) and housing period (H-study). The number of cows in each study was 3078 (49 herds) and 3190 (47 herds), respectively. Due to a different hoof trimming strategy, data collected during both observation periods in SY herds (638 cows; 16 herds) were combined. Cows in straw yards (SY) had by far the lowest numbers of claw disorders. Over 80% of cows exposed to concrete flooring had at least one claw disorder at the time of observation, whereas on SY surfaces, this percentage was between 55 and 60. Cows on SLSCR were less frequently affected by interdigital dermatitis/heel erosion (IDHE) and digital dermatitis (DD) than cows on SL (reference floor system). Little difference in claw health was found between SCF and SL. The ZG cows were at higher risk (OR > 2) for most claw disorders in the P-study, whereas in the H-study, ZG cows showed less IDHE, sole haemorrhage, and sole ulcer. All herds on concrete flooring (SL, SL-SCR, SCF, ZG) were infected by DD, resulting in an average cow level prevalence of 30%. This indicates that the level of DD infection has increased considerably over the last 10 yr in The Netherlands.

Abbreviation key: DD = dermatitis digitalis, **H-study** = housing study, **HYP** = interdigital hyperplasia, **IDHE** = interdigital dermatitis/heel erosion, **IP** = interdigital phlegmon, **OR** = odds ratio, **P-study** = pasture study, **P/H-study** = merged pasture and housing study, **SCF** = solid concrete floor, **SH** = sole haemorrhages, **SL** = slatted floor, **SL-SCR** = slatted floor with manure scraper, **SOC** = solar contusion, **SUL** = sole ulcer, **SY** = straw yard, **WLA** = white line abscess, **WLS** = white line separation, **ZG** = zero-grazing.

INTRODUCTION

Claw disorders are frequently reported in dairy cattle all over the world. Weaver (2000) reported that diseases of the claw account for about 90% of all lameness incidents. Claw disorders are distinguished at clinical level (i.e. being lame) and at subclinical level (i.e. digital disorders recognisable at hoof trimming). Disturbed claw health is an unequivocal source of suffering for the cows (Webster, 1995), because the disorder is usually long term and painful (Alban, 1995). The Dutch Advisory Board for Animal Affairs (RDA) has considered actual levels of clinical (30% cow cases per year) and subclinical claw disorders in The Netherlands as unacceptable from an animal welfare point of view (RDA, 1996). In other countries, the prevalent lameness rates are also stated as not acceptable, and they give rise to a growing concern about animal welfare (Farm Animal Welfare Council, 1997).

Lameness is characterised as a multifactorial condition. It is the result of an interaction between housing design, farm management, nutrition, and animal characteristics (Clarkson et al., 1993). Because lameness incidence is higher in the winter period when cows are housed indoors compared to periods when animals have access to pasture (Leaver, 1988; Faye and Lescourret, 1989; Webster, 1995), it is obvious that the housing environment has a large impact. Floors are hypothesised as a crucial factor in locomotion and claw health (Albright, 1995).

Several studies have evaluated the incidence of lameness under different housing and flooring circumstances. Concrete flooring, characterised as abrasive and unyielding, and uncomfortable stalls have been associated with a higher incidence of lameness (Vokey et al., 2001). A direct relationship between housing conditions and several digital disorders has been shown experimentally (Bergsten, 1995; Vermunt and Greenough, 1996). Frequently, it has been reported that loose cubicle housing increases the incidence of lameness compared with tied housing (Maton, 1987; Thysen, 1987; Faye and Lescourret, 1989; Clarkson et al., 1993; Hultgren, 2002). Epidemiological studies in The Netherlands (Frankena et al., 1991) and in France (Faye and Lescourret, 1989) revealed that claw health was worse during indoor cubicle housing than during pasturing. Following those findings, the effect of all year round indoor cattle housing on hoof health was investigated in zero-grazing herds. Several claw disorders appeared to be more prevalent under zero-grazing circumstances in Dutch dairy farms (Smits et al., 1992). Zero-grazed cattle in small-scale Kenyan herds had a three times higher risk for a lameness event than cattle that had access to pastures (Gitau et al., 1996). These lameness surveys underline the seriousness of hoof problems resulting from modern dairy housing facilities.

Given the incidence of claw and lameness problems on traditional concrete flooring, the possibilities of softer, more natural flooring properties in livestock housing have also been investigated. Beneficial effects of deep litter straw-based systems have been suggested from an animal welfare point of view (ADAS, 1994; Singh et al., 1994). Indeed, better claw health was found in beef cattle (Maton, 1987; Murphy et al., 1987) and in dairy calves (Frankena et al., 1993) kept in straw yards rather than on slatted floors. But to what extent the same applies for dairy cattle housed in straw-yard systems is unclear.

In a recent study aimed at welfare assessment, Fregonesi (1999) showed that dairy cows had a clear preference for standing on a soft surface such as that in straw-yard systems rather than on a concrete floor, as in cubicle housing systems. In contrast, no significant differences in hoof dimensions, locomotion score, or clinical lameness were found between those two housing systems (Fregonesi and Leaver, 2000). Hughes et al. (1997) reported a significant reduction in incidence and prevalence of lameness in a three-herd study after changing from cubicle housing to straw yards. Both positive (reduction in sole and white line haemorrhages) and negative effects (increase in heel horn erosion) on claw health were found in an experimental study in heifers transferred from cubicle yards into straw yards (Livesey et al., 1998).

The design of livestock housing widely differs in many parts over the world. Cubicle housing system with a concrete floor is the predominant housing type for dairy cattle in The Netherlands. Approximately 90% of the dairy cows are kept in cubicle houses with a slatted floor (Braam and Swierstra, 1997), while about 10% are kept on solid concrete floors with scraper. A very small percentage of cows are housed in tie stalls or straw-yard systems. In recent years, two trends are apparent in modern Dutch dairy production. First, through the introduction of robotic milking, more stringent manure legislation, and cost price reduction, an increasing number of dairy cattle are being housed indoors throughout the year. Second, a more extensive organic farming system is developing in which cows are often housed in a straw yard.

Lowering the prevalence of claw disorders and lameness incidents in current housing systems requires more insight into the floor factors which are involved. The urgency of research is increased by the mentioned developments in housing intensity and -design. The objectives of this study are (1) to investigate prevalence and severity of claw disorders at subclinical level in a large sample of the Dutch dairy cattle population and (2) to assess the effect of various flooring systems on that prevalence.

MATERIALS AND METHODS

Study Design and Population

The study can be characterised as a cross-sectional observational study for prevalence estimation (Thrusfield, 1986). Claw health was recorded on 86 dairy farms. Observations at hoof trimming events occurred within the specific changeover periods between pasturing and housing (Autumn 1999) and vice versa (Spring 2000). Only cows that were at least 50 d at pasture at the time of hoof trimming, and not longer than 15 d housed indoors were included in the pasture study (**P-study**). Cows included in the housing study, (**H-study**), were housed for at least 50 d indoors, and thereafter no longer than 15 d at pasture during daytime. Due to a different hoof trimming strategy in most straw yard (**SY**) herds, it was decided to place all data collected in SY herds within both observation periods and analyse them together in a merged pasture and housing study (**P/H-study**).

Herds involved in the study were selected from lists of clients of Agricultural Consultancy Service (DLV), Agricultural Farm Service (ABV), and local professional hoof trimmers. Farms with either a slatted floor **(SL)**, slatted floor with manure scraper **(SL-SCR)**, solid concrete floor **(SCF**, always with manure scraper), or a SY loose-housing system, with or without a small concrete walking area behind the feeding rack, were included. In addition to the floor system, other selection criteria were: herd size > 25 cows, herd milk yield > 7000 kg/ cow/yr, member of the Dutch herdbook milk-recording system (Royal Dutch Dairy Syndicate, NRS), and routine herd hoof trimming twice a year. Herds kept on concrete floor systems (SL, SL-SCR, SCF) were primarily pure Holstein and

Holstein crossbreeds. In SY herds, besides Holstein breeds, other breeds were found, such as Dutch-Friesian, Jersey, and Mont-Beliardes.

Most herds in this study had access to pasture in the summer season. Some farms (n = 13), however, had housed their cows indoors all year round. These zero-grazing **(ZG)** herds were analysed separately as a distinctive farming system. Ten ZG herds had a SL, two had a SCF, and one had a SL-SCR. In general, SY farms are characterised by a less-intensive management than conventional dairy farms, resulting in herd milk yield < 7000 kg/cow per year in nine out of the 16 SY study farms, and no herd hoof trimming has been done routinely twice a year in most study SY herds (except for one herd); eight SY farms trimmed once a year, while seven other SY farms had not trimmed their herds for at least 5 yr. Although short of the selection criteria, the SY farms were included in the study because of their interesting floor system from a claw health point of view.

Claw health records of 3078 cows (49 herds), 3190 cows (47 herds), and 638 cows (16 herds) in the P-, H-, and P/H-study, respectively, were used for descriptive analysis. The distribution of P-, H-, and P/H-study population within each floor system, as well as distributions of parity, stage of lactation and 305-d herd production are shown in Table 1. Herd level and individual level milking information were obtained from computerised milking records.

Diagnoses

All claw lesions were recorded during routine herd trimming visits. Professional hoof trimmers conducted the trimmings. The first author made the claw observations in assistance with a group of animal science students. These students were trained in diagnosing claw disorders by studying photographs of affected claws and through live demonstration by a hoof-trimming expert employed by the Utrecht Faculty of Veterinary Medicine. The first author checked at several times during this study to determine whether claw examinations done by the students agreed with his diagnostic opinion, regarded as standard in this study.

Hooves of hind legs of each animal were examined for the presence and severance of claw disorders. Interdigital dermatitis (ID) and its resulting symptom heel horn erosion (HE) were diagnosed together as **IDHE**. IDHE was rated on a scale of 0 to 3, based on the definitions of Peterse (1980): 0, no signs; 1, slight pock marking and/or superficial horn defects in the axial surface of the bulb; 2, some big fissures or grooves in the horn of the bulb and/or sole, not extending to the corium; 3, disappearance of heel horn and/or deep defects in the horn of bulb or sole, extending to the corium.

Diagnosis of lesions of digital dermatitis (**DD**) was based on the classification developed by Döpfer (1994). DD is synonymous with PPD (papillomatous digital dermatitis), a name recently introduced in North America (Read and Walker, 1998). In our study the presence of active, classical ulcerative lesions, characterised by a red granular strawberry-like surface (Read et al., 1992) and classified by Döpfer as disease stage M1 and M2, were recorded. Other clinical signs associated with M1 and M2 were pain reactivity

Table 1. The relative frequency distribution of parity, stage of lactation, average 305-d herd milk yield, and median herd size in the P- (pasture period 1999), H- (housing period 2000), and P/H-study (pasture 1999 + housing 2000). (SL = slatted floor; SL-SCR = slatted floor with manure scraper; SCF = solid concrete floor; ZG = zero-grazing; SY = straw yard).

	P-STUDY				H-STUDY				P/H-STUDY
	SL	SL-SCR	SCF	ZG	SL	SL-SCR	SCF	ZG	SY
Parity									
1	32.6	36.1	29.3	37.4	33.7	34.2	33.0	32.3	26.7
2	25.4	22.8	29.7	30.3	25.5	28.2	31.6	30.3	20.5
3	20.3	16.7	16.3	14.3	18.7	12.9	16.7	18.1	15.7
≥4	21.7	24.4	24.7	18.0	22.2	24.7	18.7	19.4	37.2
Stage of lactation									
- Pre top [0-60]	21.4	17.2	18.4	20.4	16.1	15.8	17.2	13.4	15.1
- Top [60-120]	14.0	13.1	18.4	18.4	16.8	21.0	16.3	17.3	16.5
- Past top [>120]	49.4	56.1	49.8	49.2	53.7	50.3	54.8	57.9	58.6
- Dry	15.2	13.6	13.4	12.0	13.4	12.9	11.7	11.4	9.9
305-d herd yield (kg)	8390	9296	8237	9029	8439	9010	8262	8993	6710
Range	7166-9461	8242-10,468	6808-10,998	8095-10,126	7604-9461	8214-10,365	7021-9618	8095-10,126	4125-9605
Median herd size	60	66	59	76	60	69	59	94	46
Range	32-89	55-73	29-89	36-285	40-89	55-82	36-89	36-285	25-68
Number of cows	1116	360	875	727	933	596	557	1104	638
Number of farms	19	6	16	8	15	9	10	13	16

[1] Dry cows included

after palpation, foul odour and swelling at the affected site. M1 (= DD grade 1) is defined as an early stage of DD with a circumscribed granulomatous area, 0.5 to 2 cm in diameter. A circumscribed classical ulceration area more than 2 cm in diameter, and two or more (smaller) affected spots within the same claw have been classified as M2 (= DD grade 2).

In the case of scoring sole haemorrhages (**SH**), the surface of each claw was divided into six zones according to recommendations established on the VIth Symposium on Diseases of the Ruminant Digit (Liverpool, 1990). Zones 1, 2, and 3 made up the white line, zones 4 and 5 the sole, and zone 6 the heel. The severity of SH was evaluated for each of the six zones by density and extent the haemorrhage, based on the method proposed by Greenough and Vermunt (1991): 0, no or slight yellow discoloration; 1, slight red discoloration, occurring of in stripes or small spots; 2, moderate haemorrhage; 3, severe haemorrhage; 4, exposed corium/sole ulcer.

Ulcerations in zones 4 (sole ulcer), 5 (toe ulcer), and 6 (heel ulcer) were combined and reclassified as sole ulcer (**SUL**). An earlier stage of ulceration, when the corium was not exposed, was scored as solar contusion (**SOC**). An early stage of white line disease (zones 1, 2, and 3) was characterised as white line separation (**WLS**). White line abscess (**WLA**) was defined as an advanced stage of white line disease, when a white line separation has progressed to the level of the corium resulting in abscess formation. The disorders interdigital hyperplasia (**HYP**) and interdigital phlegmon (**IP**) were diagnosed as being present (1) or not (0).

Data Analyses

All data analyses were performed using the statistical packages SAS (1996) and SPSS (2002). Claw health was assessed in terms of prevalence rates for all claw disorders (except IP). Prevalence rate was calculated as the proportion of animals with the outcome of a given claw disorder. For each claw disorder, the highest score within any hind claw was set as the final outcome for the cow. In addition to cow level prevalence, herd prevalence rates were calculated for IDHE, DD, and SH (as being most frequent disorders).

Associations between floor system and the occurrence of a specific claw disorder were estimated using a binomial distribution and a logistic link function (logistic regression) in PROC GENMOD of SAS. Polytomous variables (e.g. IDHE, DD, SH) were reduced into dichotomous outcomes (i.e. a cow was positive or negative for a certain claw disorder at the time of observation). When analysing IDHE, we distinguished slight, superficial IDHE from serious and severe IDHE lesions. A cow was scored IDHE-positive when she had IDHE lesions grade 2 or 3; superficial IDHE (grade 1) was assumed as IDHE-negative. Scores for DD and SH were dichotomised as follows: DD grade 1 and 2, and SH grade 1, 2, 3, and 4 were assumed as DD- and SH-positive, respectively. Cows within one herd are all exposed to the same environmental circumstances and, subsequently, cannot be considered as independent units in the analysis. Therefore, the standard errors of the regression coefficients were scaled by a factor equal to the square root of the reciprocal of the Pearson chi-square, which takes the dependence into account and will result in increased *P*-values.

Odds ratios **(OR)** were calculated, indicating the estimated risk for the outcome of a claw disorder at a certain floor system, relative to the estimated risk at the reference floor system (OR = 1). SL was set as reference floor system, since it is the predominant floor system for dairy cattle in The Netherlands. Associated *P*-values were calculated to test whether or not odds of claw disorders differ significantly between SL and other floor systems (SL-SCR, SCF, ZG, and SY). The differences in mean herd prevalence rates between the P-, H-, and P/H-study were tested using the Kruskal-Wallis one-way ANOVA on ranks ($\alpha = 0.05$). The Mann-Whitney U test was performed to analyse differences in prevalence rates of ZG cows in the H-study. The Wilcoxon Signed Ranks test was used to examine seasonal differences in prevalence rates of ZG cows that were present in both the P- and H-study. For all analyses, differences were considered significant when $P \leq 0.05$.

RESULTS AND DISCUSSION

Study population

The median herd size in the P- and H-study populations (60 and 64 cows, respectively; dry cows included) was higher than the average herd size of dairy farms participating in the Dutch milk recording system (51 cows, CBS, 2000). In both the P- and H-study, ZG herds showed highest median herd size: 76 and 94 cows, respectively. The average 305-d herd milk yield in our study farms (8555 and 8664 kg in the P- and H-study, respectively) was also higher than that in the Dutch milk recording population (8222 kg; LEI and CBS, 2001). The average 305-d herd milk yield was highest in SL-SCR herds: 9296 and 9010 kg in the P- and H-study, respectively. Although numerous authors have associated herd size and milk yield with higher overall incidence of lameness (Gröhn et al., 1992; Alban, 1995) and higher levels of claw disorders, such as DD (Wells et al., 1995, 1999) and IDHE (Frankena et al., 1993), it can be argued whether the small deviation in herd characteristics between our study population and those in an average Dutch dairy herd actually biased our prevalence rates. We believe that, because of the large-scale study population in both the P- and H-study and the well-defined selection criteria, farms included in the current study make up a good representation of common Dutch dairy farms, and subsequently, our findings reflect the current situation with respect to claw health in dairy cows housed in loose, cubicle housing systems in The Netherlands.

In SY herds, both median herd size (46 cows) and average 305-d herd yield (6710 kg) were lower than those in the milk recording population. As mentioned before, high-milk-yield dairy cows are at higher risk for lameness events at both clinical and subclinical level. In addition to lower herd size and herd milk yield, SY herds have also a lower percentage of Holstein-Friesian cattle in favour of less lameness-susceptible breeds such as Mont-Beliardes and Jersey (Peterse, 1985). Besides the possible benefit of a soft floor surface, lower prevalence rates in SY herds may be partially explained by bias due to such negatively associated factors.

Cow Level Prevalence

Claw disorders per cow. The majority of cows had claw disorders at subclinical level. Within cows exposed to concrete flooring (SL, SL-SCR, SCF, and ZG), 78% in the P-study and 81% in the H-study had at least one claw disorder (based on dichotomous outcomes, i.e. IDHE grade 1 = IDHE-negative) at the time of hoof trimming (Figure 1). Many cows showed one or two claw disorders in both the P- (36.2 and 26.2%, respectively) and H-study (36.8 and 28.7%, respectively). Approximately 4% of the cows exposed to concrete flooring in the P-study and 2.9% in the H-study had four or more claw disorders. Compared with concrete flooring, the number of claw disorders per cow was considerably lower on SY farms where 42.5% of the cows were free of any claw disorder at the time of observation. About 40% of the SY cows showed one claw disorder, whereas the remainder had two (14.7%) or three (2.2%) claw disorders.

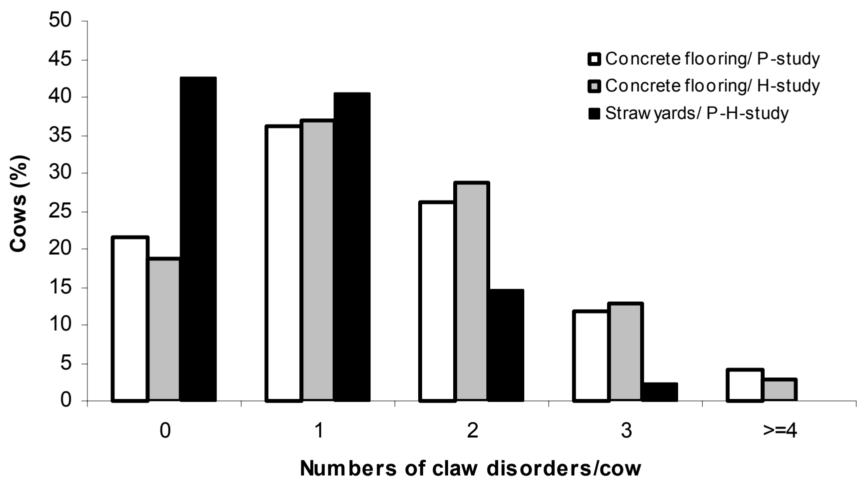

Figure 1. Distribution of the number of claw disorders per cow (based on binary data, i.e. IDHE grade 1 = IDHE-negative) in Dutch dairy cows exposed to concrete floor systems in the P- (pasture period 1999) and H-study (housing period 2000), and exposed to straw yards in the P/H-study (pasture 1999 + housing 2000).

Seasonal Influence. Table 2 shows the original ordinally scored cow level prevalence rates for IDHE, DD, and SH observed on different floor systems. IDHE was the most frequent disorder, but many cows were just mildly affected (grade 1; on average 32.7 and 41.4% in the P- and H-study, respectively). This agreed with findings in three earlier Dutch epidemiological studies (Peterse, 1980; Frankena et al., 1991; Smits et al., 1992).

Moreover, we found that IDHE lesions were more prevalent and more severe in the housing period than during grazing, which confirms that IDHE infection has a seasonal pattern, and the degree of affection is highest at the end of the housing period, as described earlier (Peterse, 1980, 1987; Frankena et al., 1991).

A beneficial effect of grazing on the prevalence of DD lesions, as suggested by Frankena et al. (1991), could not be determined in our study. Within cows exposed to concrete flooring with grazing facilities (SL, SL-SCR, and SCF), the level of DD infection was almost similar in the P- and H-study (on average 27.7and 27.9%, respectively). Furthermore, prevalence rates of DD have increased considerably in comparison with the situation 10 yr ago reported by Frankena et al. (1991); then, 8.1 and 13.8% of the cows in the study population were affected by DD at the end of the pasture and housing season, respectively.

Table 2. Cow prevalence per severity of lesion of interdigital dermatitis/heel erosion (IDHE), dermatitis digitalis (DD) and sole haemorrhages (SH) in dairy cows exposed to concrete floor systems in the P- (pasture period 1999) and H-study (housing period 2000), and in straw yards (SY) in the P/H-study (pasture 1999 + housing 2000). (SL = slatted floor; SL-SCR = slatted floor with manure scraper; SCF = solid concrete floor; ZG = zero-grazing).

	P-STUDY				H-STUDY				P/H-STUDY
Diagnosis	SL	SL-SCR	SCF	ZG	SL	SL-SCR	SCF	ZG	SY
IDHE grade 0	44.6	52.5	35.5	31.8	7.3	19.8	10.2	16.1	29.6
grade 1	34.7	32.8	34.1	27.9	42.0	44.3	37.4	41.2	57.1
grade 2	18.5	13.1	26.2	29.9	45.3	34.1	48.1	40.4	13.3
grade 3	2.2	1.7	4.2	10.5	5.4	1.8	4.3	2.3	0.0
DD grade 0	70.3	72.5	74.6	51.0	69.3	79.9	68.8	69.3	96.1
grade 1	17.7	17.5	12.2	17.5	13.9	10.2	10.0	10.0	2.5
grade 2	11.9	10.0	13.1	31.5	16.8	9.9	21.2	20.7	1.4
SH grade 0	54.9	52.2	53.0	36.7	52.3	44.3	54.8	68.8	75.7
grade 1	32.9	34.7	34.2	40.6	29.4	33.4	20.1	21.5	16.1
grade 2	8.9	10.6	10.1	16.2	14.5	16.8	17.8	8.1	6.7
grade 3	2.9	2.5	2.5	5.4	3.7	4.3	6.8	1.4	0.9
grade 4	0.5	0.0	0.2	1.1	0.1	1.2	0.5	0.2	0.5

Differences in prevalence rates of claw disorders in the P-, H-, and P/H-study might have its origin in several causes. First, in some marginal cases, differences in the interpretation of presence and severity of a claw disorder may have occurred due to inter- and intra-observer variation. For example, in scoring the severity of IDHE, DD, and SH, when distinguishing between a slight (grade 1), or more serious lesion (grade 2 or higher). The borderline between these two disease stages can be doubtful in some cases. In common, however, this was considered of minor importance because most claw disorders and symptoms are well recognisable, observers were specially trained, and observers' records were regularly checked during the observation period. Second, the time period between two consecutive herd-trimming events was not taken into account in the present analysis. The importance of hoof trimming interval when interpreting claw health records has been recognised by Enevoldsen and Gröhn (1991). Hoof trimming, as part of the farm management, can be used either as a preventive or curative tool. If study herds have brought forward their date of herd trimming in order to prevent serious claw problems, this might result in an underestimation of the prevalence rates for certain claw lesions. Other farmers, however, may have been less attentive to their cattle's claw health, allowing a longer time period between two herd trimmings, i.e. an overestimation. Third, farms included in the P-study were not necessarily the same as those in the H-study. In total, 35 farms were included in both the P- and H-study; 26 farms were included once, either in the P- or H-study. (Some farms could not be visited twice because herd trimming coincided on several farms; other farms were not included in the P- or H-study analysis because they exceeded the definitions of either pasture or housing period). Finally, the level of exposure to some risk factors for claw disorders may have varied between pasture and housing period, resulting in differences in prevalence rates. An inventory of potential cow and environmental risk factors was also part of the present study. Results of the risk analyses will be reported separately.

Herd Level Prevalence

IDHE. Figure 2 shows the distribution of herd prevalence rates for serious IDHE among herds with concrete flooring and in SY herds. All herds with concrete flooring in the P- and H-study had cows that showed serious IDHE lesions (grades 2 and 3). Herd prevalence ranged between 3 and 92% in the P-study (median = 24.2%), and between 2 and 93% in the H-study (median = 48.8%), whereas in SY herds this range was between 0 and 49% (median = 5.7%). The Kruskal-Wallis Multiple Comparison Z-Value test ($\alpha = 0.05$) showed that the differences in IDHE herd prevalence rates were significant between the P- and H-study, as well as between cows on concrete flooring in the H-study and cows in SY herds in the P/H-study.

DD. Mean herd prevalence rates for DD varied greatly (Figure 3), ranging between 2 and 73% in the P-study (median = 27.6%) and 1 and 65% in the H-study (median = 24.4%). These numbers suggest that the level of DD infection in The Netherlands has become worse over the last decade. In a similar observational field study under 59 Dutch dairies, Frankena et al. (1991) reported that in the majority of herds, <15% of the cows were affected by DD. Moreover, since then the disease has become more widespread among dairy herds. Approximately 19 and 7% of the herds studied by Frankena et al. (1991) were not affected by DD at the end of the pasture and housing period, respectively. In our study, however, none of the herds in the P- and H-study were free of DD lesions. A marked contrast was seen in SY farms, where almost 65% (n=10) of the herds were completely free of DD (median = 0.0%; range = 0 to 29%) Differeces in mean DD herd prevalence rates between SY farms and farms having concrete flooring in either the P- or H-study were tested as significant (Kruskal-Wallis test).

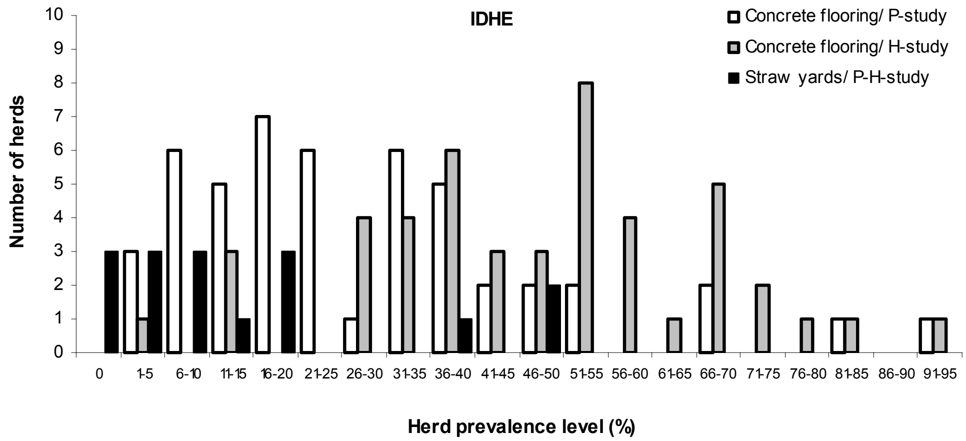

Figure 2. Distribution of herd prevalence rates for serious interdigital dermatitis/heel erosion (IDHE) in Dutch dairy cows exposed to concrete flooring in the P- (pasture period 1999; n = 49 farms) and H-study (housing period 2000; n = 47 farms), and exposed to straw yards in the P/H-study (pasture 1999 + housing 2000; n = 16 farms).

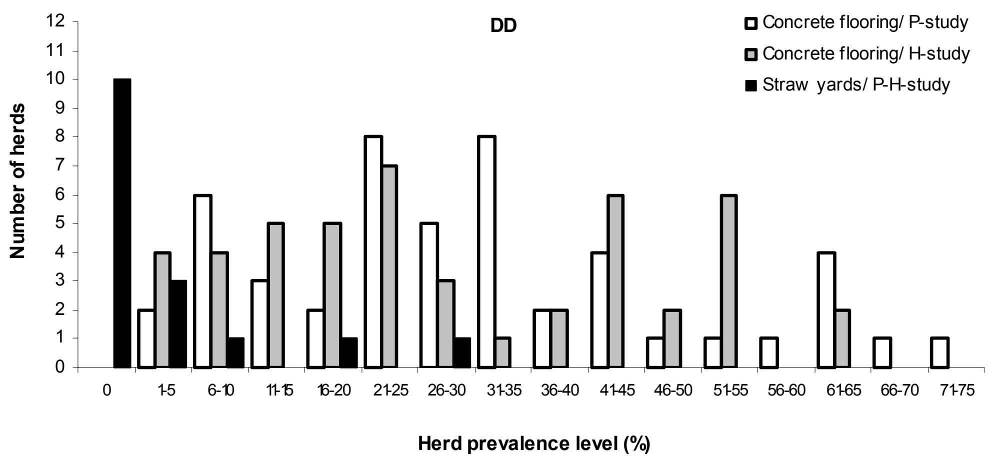

Figure 3. Distribution of herd prevalence rates for digital dermatitis (DD) in Dutch dairy cows exposed to concrete flooring in the P- (pasture period 1999; n = 49 farms) and H-study (housing period 2000; n = 47 farms), and exposed to straw yards in the P/H-study (pasture 1999 + housing 2000; n = 16 farms).

SH. Herd prevalence rates for SH were significantly lower for SY herds (range: 3 to 55%; median = 28.8%) compared with herds on concrete flooring (Figure 4); SH prevalence at herd level varied between 10 and 83% in the P-study (median = 54.1%), and 9 and 80% in the H-study (median = 41.2).

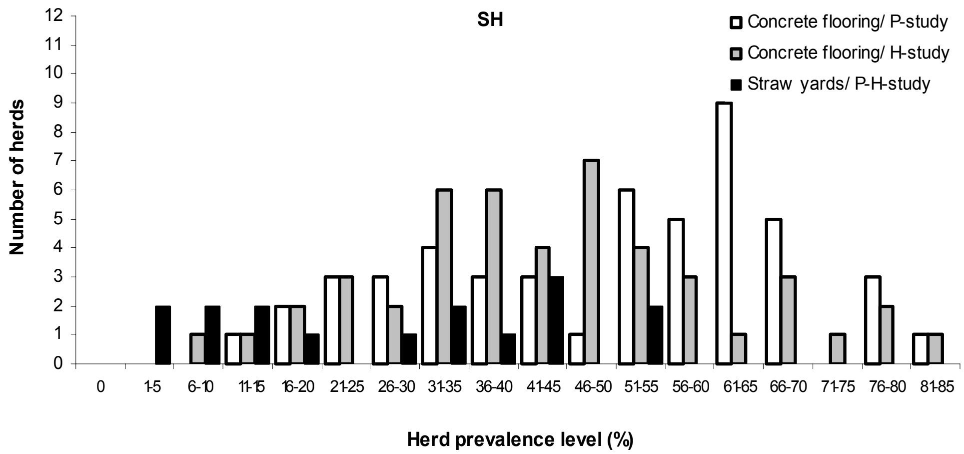

Figure 4. Distribution of herd prevalence rates for sole haemorrhages (SH) in Dutch dairy cows exposed to concrete flooring in the P- (pasture period 1999; n = 49 farms) and H-study (housing period 2000; n = 47 farms), and exposed to straw yards in the P/H-study (pasture 1999 + housing 2000; n = 16 farms).

Influence of Floor System on Claw Disorders

The influence of floor system on the occurrence of claw disorders is presented in Table 3. Prevalence rates for the examined claw disorders (except IP) are given, as well as OR and associated *P*-values. The small number of IP cases we found is due to the fact that claw health was assessed in a cross-sectional study; IP is acute by nature, and its symptoms are short-lived when immediate treatment is practiced. Before analysing, the ordinally scored prevalence rates for IDHE, DD, and SH (Table 2) were reduced into dichotomous data. An important consideration in the dichotomisation was the question to what extent a certain disease stage may result in negative effects on the well-being of a cow. In our opinion, slight, superficial IDHE (grade 1) causes mild inconvenience to a cow. This in contrast to more serious stages of heel erosion (IDHE grades 2 and 3), where deep clefts in the heel and bulb region result in deformation of the claw (Peterse, 1980). As a result, hoof overgrowth is induced in the affected claw, which disturbs the natural weight-bearing process within the claw (overburdening; Toussaint Raven, 1973), and subsequently may affect the locomotion pattern of a cow. Reduction of ordinal scores for DD and SH into binary scores was based on the same well-being considerations, resulting in classifying DD grades 1 and 2, and SH grades 1, 2, 3, and 4 as DD- and SH-positive, respectively.

Table 3. Analysis of the association between floor system and the presence of a claw disorder (dichotomous outcome) in the P- (pasture period 1999) and H-study (housing period 2000); bold figures give the significant difference with slatted floor (SL; = reference floor system) at the level of P < 0.05. (IDHE = interdigital dermatitis/heel erosion; DD = digital dermatitis; SH = sole haemorrhages; SOC = solar contusion; SUL = sole ulcer; WLS = white line separation; WLA = white line abscess; HYP = interdigital hyperplasia; IP = interdigital phlegmon; SL-SCR = slatted floor with manure scraper; SCF = solid concrete floor; ZG = zero-grazing; SY = straw yard).

		P-STUDY			H-STUDY		
Diagnosis	Floor system	Prevalence[1]	OR	*P*-value	Prevalence[1]	OR	*P*-value
IDHE	SL	20.7	Ref.[2]	–	50.7	Ref.[2]	–
	SL-SCR	14.7	0.66	0.415	35.9	0.54	0.059
	SCF	30.4	1.67	0.106	52.4	1.07	0.829
	ZG	40.3	2.59	**0.003**	42.7	0.72	0.226
	SY[3]	13.3	0.59	0.209	13.3	0.15	**0.001**
DD	SL	29.7	Ref.[2]	–	30.8	Ref.[2]	–
	SL-SCR	27.5	0.90	0.795	20.1	0.57	0.155
	SCF	25.4	0.81	0.483	31.2	1.02	0.952
	ZG	49.0	2.28	**0.006**	30.7	1.00	0.993
	SY[3]	3.9	0.10	**0.001**	3.9	0.09	**0.001**
SH	SL	45.1	Ref.[2]	–	47.7	Ref.[2]	–
	SL-SCR	47.8	1.11	0.738	55.7	1.38	0.233
	SCF	47.0	1.08	0.753	45.2	0.91	0.720
	ZG	63.2	2.10	**0.005**	31.2	0.50	**0.003**
	SY[3]	24.3	0.39	**0.002**	24.3	0.47	**0.006**
SOC	SL	11.0	Ref.[2]	–	7.2	Ref.[2]	–
	SL-SCR	12.8	1.18	0.600	6.5	0.91	0.784
	SCF	11.1	1.01	0.979	10.1	1.44	0.265
	ZG	11.3	1.03	0.921	2.9	0.39	**0.013**
	SY[3]	5.0	0.41	**0.014**	5.0	0.66	0.286
SUL	SL	3.3	Ref.[2]	–	3.2	Ref.[2]	–
	SL-SCR	3.3	1.01	0.990	2.5	0.78	0.594
	SCF	4.3	1.32	0.385	5.8	1.83	0.114
	ZG	7.4	2.34	**0.005**	5.2	1.64	0.146
	SY[3]	2.4	0.70	0.406	2.4	0.72	0.496
WLS	SL	6.0	Ref.[2]	–	7.0	Ref.[2]	–
	SL-SCR	4.2	0.68	0.549	8.7	1.28	0.591
	SCF	5.7	0.95	0.901	7.4	1.06	0.903
	ZG	7.6	1.28	0.549	10.6	1.58	0.225
	SY[3]	26.0	5.51	**0.001**	26.0	4.70	**0.001**
WLA	SL	3.1	Ref.[2]	–	1.4	Ref.[2]	–
	SL-SCR	2.8	0.91	0.834	1.2	0.84	0.748
	SCF	2.3	0.74	0.405	0.7	0.51	0.307
	ZG	4.0	1.32	0.382	2.5	1.84	0.114
	SY[3]	0.8	0.25	**0.021**	0.8	0.56	0.335
HYP	SL	5.1	Ref.[2]	–	4.3	Ref.[2]	–
	SL-SCR	3.3	0.64	0.352	3.0	0.70	0.401
	SCF	6.1	1.20	0.534	5.8	1.36	0.398
	ZG	11.1	2.33	**0.002**	10.8	2.70	**0.001**
	SY[3]	1.1	0.21	**0.008**	1.1	0.25	**0.024**
IP*	SL	2 **			0 **		
	SL-SCR	0			0		
	SCF	1			4		
	ZG	3			4		
	SY[3]	0			0		

* Insufficient cases for statistical analysis; ** Number of cases

[1] Prevalence based on dichotomous outcomes; [2] Reference floor system; [3] SY farms coming from merged P/H-study

SL. SL was chosen as the reference floor system.

SL-SCR. Cows exposed to SL-SCR showed lower prevalence rates for infectious claw lesions (e.g. IDHE, DD, and HYP) than cows on SL (Table 3). Also, for the estimated OR for IDHE, DD, and HYP in the P- and H-study (ranging mainly between 0.5 and 0.7), a certain potential benefit of the SL-SCR is indicated, though statistical significance is lacking. Wet floor conditions are associated with a higher overall lameness prevalence in US dairy herds (Wells et al., 1995, 1999), and a higher IDHE (Thysen, 1987) and DD incidence (Rodriguez-Lainz et al., 1996) in particular, the use of a manure scraper may reduce these negative effects.

SCF. Thysen (1987) demonstrated that severe IDHE and SUL were more prevalent on SCF than on SL. These observations were partially confirmed in our survey, since cows kept on SCF tended ($P = 0.11$) to have higher odds for IDHE lesions (OR = 1.7) in the P-study, and SUL (OR = 1.8) in the H-study than cows kept on SL. No other differences in prevalence rates could be determined between cows exposed to SCF and SL.

ZG. In a similar observational field study in 34 Dutch zero-grazing dairies, Smits et al. (1992) reported higher prevalence of IDHE, DD, HYP, and WLA in ZG cows compared with cows at pasture. Our results in the P-study are consistent with this report. Compared to cows on SL, cows in ZG herds in the P-study had a significantly ($P < 0.01$) higher odds for IDHE (OR = 2.6), DD (OR = 2.3), SH (OR = 2.1), SUL (OR = 2.3), and HYP (OR = 2.3). It is noted that, especially in the P-study, the level of exposure to some risk factors differs between ZG cows and cows with grazing facilities. In the H-study, only HYP (OR = 2.7) was significantly more prevalent, whereas SUL and WLA tended ($P = 0.11$; OR = 1.8) to be more prevalent in ZG than in SL cows. Moreover, significantly less SH (OR = 0.5) and SOC (OR = 0.4) were found.

In contrast to cows exposed to concrete floor systems with grazing (SL, SL-SCR, SCF), overall prevalence rates in ZG cows were similar (IDHE, HYP) or higher (DD, SH, SOC, SUL) in the P- than in the H-study. A possible explanation for the difference in prevalence rates between the P- and H-study in ZG cows could be a difference in study population between both seasons. All eight ZG herds included in the P-study were also part of the ZG study population in the H-study (n = 13 herds). An additional analysis is presented in Table 4 which illustrates that prevalence rates for DD and HYP were significantly higher ($P < 0.01$) in the group of eight ZG herds (group P&H) compared with five ZG herds that were additionally included in the H-study (group H). However, prevalence rates for IDHE, SH, SUL, SOC, and IP in the H-study did not structurally differ between those two groups, suggesting that differences in ZG-study population only partially accounts for the lower prevalence rates observed in ZG herds in the H-study. In Table 5, changes in prevalence rates are tested within a group of 536 ZG cows that were included in both the P- and H-study. It shows that prevalence rates for DD, SH, and SOC decreased significantly ($P < 0.001$) between the P- and H-study, whereas HYP significantly increased ($P < 0.001$). Because housing conditions and cow factors (except for a 6-mo increase in age) remain unchanged throughout this period in ZG herds, other farm factors (e.g. management routines, feeding rationing) may play a role in the occurrence of these claw disorders.

Table 4. Analysis of differences in cow prevalence rates in the H-study between two groups of zero-grazing (ZG) herds; group P&H contains eight ZG herds included in both the P- (pasture period 1999) and H-study (housing period 2000); group H contains five ZG herds included in the H-study only; bold figures give the significant difference at $P < 0.05$. (IDHE = interdigital dermatitis/heel erosion; DD = digital dermatitis; SH = sole haemorrhages; SOC = solar contusion; SUL = sole ulcer; WLS = white line separation; WLA = white line abscess; HYP = interdigital hyperplasia; IP = interdigital phlegmon).

	Prevalence rate[1]		Difference	
Claw disorder	Group P&H	Group H	between the groups	Mann-Whitney U test
IDHE	42.8	42.6	+0.2	0.954
DD	37.4	19.8	+17.6	**0.000**
SH	29.8	33.3	-3.5	0.219
SOC	3.2	2.4	+0.8	0.404
SUL	4.8	5.7	-0.9	0.546
WLS	10.3	11.1	-0.8	0.662
WLA	2.5	2.4	+0.1	0.915
HYP	13.7	6.1	+7.6	**0.000**
IP	0.4	0.2	+0.2	0.583

[1] Prevalence rate at cow level; based on dichotomous outcome

Table 5. Analysis of differences in cow prevalence rates between the P- and H-study using 536 zero-grazing cows that were included in both the P- (pasture period 1999) and H-study (housing period 2000); bold figures give the significant difference at $P < 0.05$. (IDHE = interdigital dermatitis/heel erosion; DD = digital dermatitis; SH = sole haemorrhages; SOC = solar contusion; SUL = sole ulcer; WLS = white line separation; WLA = white line abscess; HYP = interdigital hyperplasia; IP = interdigital phlegmon).

	Prevalence rate[1]		Difference	Wilcoxon signed
Claw disorder	Group P&H	Group H	between the groups	ranks test
IDHE	41.8	43.5	-1.7	0.494
DD	45.1	36.0	+9.1	**0.000**
SH	64.4	26.1	+38.3	**0.000**
SOC	10.8	3.4	+7.4	**0.000**
SUL	6.5	5.0	+1.5	0.217
WLS	8.4	11.8	-3.4	0.052
WLA	3.0	2.6	+0.4	0.715
HYP	9.0	14.2	-5.2	**0.000**
IP	0.4	0.4	0.0	1.000

[1] Prevalence rate at cow level; based on dichotomous outcome

SY. As with other studies (Maton et al., 1987; Murphy et al., 1987; Vaarst et al., 1998), we recorded more claw lesions in dairy cattle exposed to SL than to SY. Cows kept in SY showed significantly less DD (OR = 0.1), SH (OR = 0.4), SOC (OR = 0.4), WLA (OR = 0.3), and HYP (OR = 0.2) than cows exposed to SL in the P-study. Compared to cows on SL in the H-study, less IDHE (OR = 0.2), DD (OR = 0.1), SH (OR = 0.5), and HYP (OR = 0.3) was observed in cows kept in SY. Conversely, cows in SY had a 5.5- and 4.7-times higher risk (odds) for WLS than cows on SL in the P- and H-study, respectively. We are unaware of published research that reports similar prevalence rates for WLS in SY systems. In our study, bias in WLS prevalence rate may have appeared by introducing the group of seven SY herds that did not regularly trim their cows. It appeared that in this group the prevalence rate for WLS was higher than among the remaining cows in SY (49.8 vs. 8.9%, respectively; $P < 0.001$). Due to the lack of preventive hoof trimming, excessive hoof growth can occur (Vermunt and Greenough, 1995), and subsequently result in overloading at specific regions of the hind lateral claw (Toussaint Raven, 1985). Another possible explanation is the fact that most cows in SY systems have to mount small concrete stair(s) several times a day when they go from the straw bedded area to the feeding rack or milking yard. It is possible that during mounting those steps, the white line area in the hoof is exposed to extra forces to such an extent that traumatic damages in the white line area result.

Impact of Claw Disorders

Welfare is an important issue with respect to lameness in dairy cows. Together with mastitis, lameness is recognised the most important health problem having a negative effect on the welfare of dairy cows (Webster, 1987; Alban, 1995; Albright, 1995). The degree of lameness depends on the severity of the pathology and is a direct result of pain on weight-bearing (Weaver, 2000). In pursuit of a sound welfare indicator, Manson and Leaver (1988) have developed locomotion score as a simple and objective tool of monitoring clinical lameness. However, the impact of subclinical lameness, e.g. the level of claw disorders, is underestimated in this method. In our study, we found that, on average 80%, of the cows exposed to concrete flooring were affected by one or more claw disorders at the same time. This high level of claw lesions has negative consequences for both animal welfare and economics. Animals may suffer from subclinical affections for a long time, as some disorders are long-lasting and painful (Alban, 1995). Even after hoof trimming and any subsequent therapy, some disorders with a chronic course (e.g. DD, SUL) may hinder cows for a long period in their normal activity pattern, locomotion, and social behaviour. Further research is needed to clarify more specifically the negative effects of different levels of subclinical lameness on animal welfare. In addition, research is necessary to explore the applicability of local soft surface areas in traditional concrete flooring systems. In this way, claw health most likely can be improved in dairy cows kept in cubicle loose housing systems.

CONCLUSIONS

The majority of cows had claw disorders at subclinical level. Many cows exposed to concrete flooring had one or two claw disorders at the same time. Cows housed in SY systems had the lowest levels of claw disorders, a marked contrast to concrete flooring. Within the studied concrete floor systems, we found some differences in claw health. In infectious claw disorders (IDHE, DD, HYP), SL-SCR indicated some beneficial effect, but more research is needed to quantify the findings further. The high prevalence rates found in ZG cows in the P-study argue in favour of grazing facilities during the summer.

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Chapter 3

Risk Factors for Digital Dermatitis in Dairy Cows Kept in Cubicle Houses in The Netherlands

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ABSTRACT

The presence of digital dermatitis (DD) in dairy cows has increased considerably over the last 10 years in The Netherlands, resulting in a current prevalence of ~ 30% in cows kept in cubicle houses. Our objective was to evaluate a diversified sample of cow- and herd-related risk factors for DD in dairy cows housed in cubicle houses with different flooring systems. Associations were analysed in random-effects logistic-regression models using 2134 cows (37 herds) and 2892 cows (47 herds) in the pasture and housing studies, respectively. The odds of having DD were increased in cows of lower parity and lactating cows. Important risk factors at herd level were: restricted grazing time, fast rise in concentrate amount after calving, feeding by-products, herd trimming only at long intervals, and introduction of dry cows into the lactating herd before calving. The odds for DD were lower if cows were housed on a slatted floor with manure scraper and provided long and wide cubicles, and if calves were reared in the dairy cows' accommodation.

Abbreviation key: **DD** = digital dermatitis

INTRODUCTION

Digital dermatitis (**DD**) is an important, widely occurring claw disease in dairy cattle, as judged by the number of reports on this subject from several European countries over the last two decades (reviewed by Berry et al., 2004). In North America, a similar foot condition with a more-papillomatous character is known as "papillomatous digital dermatitis" (PDD) (Read and Walker, 1998). Both dairy farmers and government recognise the seriousness of foot problems caused by DD, though from different perspectives. Farmers see the financial losses due to decreased milk yield, lowered reproductive performance, treatment costs and increased culling percentage in cows having DD (Rebhun et al., 1980; Nutter and Moffit, 1990; Read and Walker, 1994; Argaez-Rodriguez et al., 1997). The government is concerned because of the negative consequences of lameness in general on the well-being of animals and the fact is that lesions of DD cause severe lameness (Blowey and Sharp, 1988; Frankena et al., 1991; Read and Walker, 1994; Rodriguez-Lainz et al., 1996; Greenough and Weaver, 1997; Read and Walker, 1998).

The precise cause of DD is not understood fully. A multifactorial aetiology has been suggested (Blowey and Sharp, 1988; Clark, 1990; Mortellaro, 1994; Rodriguez-Lainz et al., 1996). Various spirochete bacteria and Gram-negative anaerobes have been isolated from DD lesions. This, and response of DD lesions to parenteral or topical antibiotics (Britt et al., 1996), suggests an infectious cause. However, no specific agent has been identified consistently, nor could the disease be reproduced from the isolated organisms. A few epidemiological studies (Frankena et al., 1991; Argaez-Rodriguez et al., 1997; Rodriguez-Lainz et al., 1999) have identified specific cow characteristics (such as lower parity, early stage of lactation, calving season) as important risk indicators for DD. At the farm level, examples of contributing factors are: increased herd size and production, limited pasturing, increased length of walking path, and adult buying-in policy (Frankena et al., 1991; Rodriguez-Lainz et al., 1996; 1999).

In the field, the treatment-and-control strategy consists of use of walk-through footbaths (Blowey and Sharp, 1988; Blowey et al., 1994), sometimes in combination with individual treatment of the affected foot with (non-)antibiotic solutions (Read and Walker; 1998; Manske et al., 2002). However, these measures seem inadequate for an effective approach of the problem in modern animal husbandry. A recently performed claw-health screening study in Dutch dairy cows (Somers et al., 2003) underlines this statement. In that study, none of the 96 studied herds where cows were kept in cubicle-housing systems were free of DD, and the overall cow prevalence level was 30%. This was a threefold-increase in DD prevalence compared to the situation 10 years before (Frankena et al., 1991).

No clear cause can be given for this substantial spread in DD prevalence among dairy cows. However, certain changes have appeared in Dutch dairy farming over the last 10 years: herd size and milk production per cow have increased (LEI and CBS, 2001), and cows are increasingly housed for a greater length of time (restricted grazing), or even housed all year round (zero-grazing). A growing concern about the adverse consequences of DD and an increasing challenge of dairy cows kept in cubicle houses (Somers et al., 2003) create a growing need for insight into current risk factors associated with DD.

Our purpose of this study was to (re-)evaluate a diverse sample of cow- and herd-related risk factors for DD both during the pasturing and housing season on Dutch dairy farms with loose housing and different flooring systems.

MATERIALS AND METHODS

Study design

We designed a cross-sectional study on Dutch dairy farms that housed their cows on a slatted floor (with or without manure scraper), a solid concrete floor, in a straw yard, or that applied a zero-grazing feeding system. Herds were pure Holstein and Holstein crossbreeds. Other inclusion criteria and characteristics of the study population have been described in the 'prevalence' part of this claw health screening study (Somers et al., 2003). Hind hooves of cows were examined for lesions of DD and other claw disorders during herd-trimming events between September 1999 and June 2000. The first author made the hoof inspections in assistance with a group of animal-science students. Information on the diagnostic training of these students is given elsewhere (Somers et al., 2003). Diagnosis of DD lesions was based on the classification developed by Döpfer (1994). An early stage of DD (= M1) was defined as an ulcerative lesion, 0.5 to 2 cm in diameter, characterized by a red, granular, strawberry-like surface. A similar circumscribed granular area but > 2 cm in diameter as well as two or more M1 lesions within the same foot were classified as M2.

Other clinical signs associated with M1 and M2 were pain reaction after palpation, foul odour and swelling at the affected region. In the analysis, a cow was classified DD-positive when she had an M1 or M2 lesion on either one or both hind feet.

To distinguish between summer and winter season, the observation period was divided into a pasture and housing study. The pasture study included cows that had been ≥ 50 days at pasture at the time of herd trimming, or not housed > 15 days after the pasture season had finished. Cows included in the housing study were housed for ≥ 50 days at the time of herd trimming, or not > 15 days at pasture after the housing season had finished.

Herd size, herd production and individual-cow information (e.g. parity, stage of lactation, predicted 305-d kg milk) were obtained from computerised milking records. Detailed information about housing characteristics, feeding strategy and management practices originated from a questionnaire completed jointly by the farmer and the first author. Dimensions of cubicles and other housing facilities were recorded during on-farm inspections.

Many housing and flooring characteristics included in the risk survey (e.g. cubicle dimensions) were missing in farms that kept their cows in a straw yard. In addition, a different hoof-trimming regimen as well as less-intensive management (resulting in lower milk yield) characterised these straw-yard herds. For that reason, we excluded straw-yard herds from the analyses presented in this paper. When analysing risk factors in the pasture study, eight zero-grazing herds were excluded due to lack of data regarding pasturing variables. In the housing study, however, all 13 zero-grazing herds were included. Finally, data coming from 37 herds (2134 cows) and 47 herds (2892 cows) were used for risk analysis of DD in the pasture and housing study, respectively.

Statistical analyses

Two multivariable logistic-regression models (one for each study period) were analysed using SAS (SAS Institute Inc., 1996) to examine the relationship between potential explanatory variables and DD presence. The model-building strategy involved several steps. The first step was a bivariable screening procedure. We used logistic regression to test for binary, polytomous and continuous explanatory variables. Continuous variables were categorised to a minimum of three groups and regression coefficients were assessed for each category (Hosmer and Lemeshow, 1989) to check for linearity. Table 1 summarises the broad range of explanatory variables tested in this study. Only variables associated with DD (likelihood-ratio test $P < 0.20$) were offered to the multivariable models.

For the multivariable analyses, the selected variables first were tested for correlation. At $r > |0.5|$, only one of the two variables was selected for further modelling. The selection was based on biologic relevance, the level of P of each variable in the initial screening, and the level of correlation with other variables. A different model-building process was followed for the pasture and housing dataset.

Table 1. Overview of tested cow- and herd-related factors in a risk study on digital dermatitis in Dutch dairy cows.

Cow: Parity, stage of lactation, 305-day milk production, presence of interdigital dermatitis and heel erosion
Housing: Floor system, length of cubicle, width of cubicle, type of cubicle, cubicle bedding, thickness of cubicle bedding, presence of cubicle gilders, presence of concentrate station, rearing calves in dairy cows' accommodation *Pasturing*: Grazing system, days housed at the end of the pasture season, days at pasture at the end of the housing period, length of walking path, region, type of soil, pH soil, field drainage *Feeding*: Maximum amount of concentrate, step-up period concentrate after calving, maize amount, roughage amount, energy-content maize, energy-content roughage, (indigestible) protein maize, (indigestible) protein roughage, by-products, minerals *Management*: Purchase of dairy cattle, dry-cow groups, introduction of dry cows into lactating herd, use of chalk in cubicles, cleaning barn, disinfecting barn *Claw-care management*: Times footbath used each year, type of footbath, cleaning claws before footbathing, interval between herd trimmings, cows trimmed individually between two herd-trimming events

Pasture study

The final model with significant predictors of DD in the pasture study was obtained after a backwards-elimination procedure ($P \geq 0.05$). In case, a variable was removed from the model and the estimates of any covariates in the model changed > 25%, that variable was considered a confounder and was retained in the model. No interactions were tested.

Because observations within the same herd are not necessarily independent, the logistic-regression model was re-run including herd as a random effect, using STATA (Stata Corporation, 1999). Doing so, will account for variation between study herds caused by unmeasured and immeasurable (but clustered) sources (Curtis et al., 1993). A general effect of adding a random effect is that the standard errors and thus the *P*-values may increase (and also βs may change). Therefore, the process of backwards elimination was used once again until only variables with $P < 0.10$ or confounders remained. Results are expressed as odds ratios (OR) and 95% confidence intervals (CI) were calculated.

Housing study

Due to a high number of potential risk factors in the housing study (about 50), subject-related variables were subcategorised into smaller groups (clusters) and each cluster was analysed separately. The clusters were: cow, housing, feeding, and management. Per cluster, logistic-regression analysis with backward selection of variables was used, similar to the procedure described for the pasture study. At the cluster level, the variable floor system (slatted, slatted with scraper, or solid concrete floor) was forced into each model. Next, the models of the four clusters were combined in a backward-stepwise selection and removal at $P \geq 0.05$. No interactions were tested. Similar to the pasture model, the factor herd was added as the random term to the multivariable model. Variables with $P < 0.10$ or confounders were retained in the model.

RESULTS

Prevalence

In the study population, the cow-level prevalence for DD was 27.3% in the pasture period and 28.5% in the housing period. About 30% of the affected cows in each period had lesions of DD on both hind feet.

Risk factors in the pasture study

In the bivariable analysis, 14 variables were associated with DD in the pasture study (not presented). Of these, variables for region and use of footbath were not included in the multivariable logistic model because of co-linearity with type of soil and days housed at the end of the pasture season, respectively.

In the final model, five variables were significantly associated with DD (two factors at $P < 0.07$; the remaining at $P < 0.05$) (Table 2); five factors were retained as confounders.

Risk factors in the housing study

After initial screening, 40 variables were associated with DD in the housing period. Of these, nine variables (cubicle bedding, concentrates station, herd size, roughage amount, number of cows trimmed individually, protein roughage, indigestible protein roughage, energy maize, indigestible protein maize) were excluded from the model-building because these variables showed moderate correlation ($r > |0.5|$) with other factors (i.e. width of cubicles, maximum concentrate amount (4x), energy roughage, maize amount, protein maize (2x), respectively).

The final model for DD in the housing study is in Table 3. Eleven variables were significantly associated with DD (two factors at $P < 0.07$; the remaining at $P < 0.05$), and four factors were retained as confounders.

Table 2. Final multivariable logistic-regression model (with herd included as random effect)[a] for the occurrence of digital dermatitis at the end of the **pasture** period 1999, for 2134 cows of 37 herds from The Netherlands.

Risk factor	Class	Frequency	Prevalence (%)	Odds Ratio	95% CI
<u>*Cow level*</u>					
Parity	1	676	30.2	1.87	1.39, 2.52
	2	569	30.8	1.77	1.31, 2.41
	3	390	27.9	1.63	1.16, 2.29
	≥ 4	499	18.8	1.00	-
Stage of lactation (d)	0-30	197	29.4	1.00	-
	31-70	287	25.4	0.89	0.57, 1.38
	> 70	1354	28.9	0.95	0.66, 1.36
	Dried-off	296	20.3	0.55	0.35, 0.86
<u>*Herd level*</u>					
Herd size[b]	< 50	345	22.6	1.00	-
	50-75	1282	27.0	1.42	0.71, 2.83
	> 75	507	31.2	1.69	0.79, 3.60
Flooring system	SL[c]	1071	28.4	1.00	-
	SL-SCR[d]	360	27.5	0.55	0.22, 1.38
	SCF[e]	703	25.5	1.25	0.66, 2.39
Grazing system	Full	1753	25.4	1.00	-
	Restricted	381	36.0	2.42[f]	0.94, 6.23
Days housed at the end of the pasture season	0-25	761	24.0	1.00	-
	26-75	1004	27.5	1.25	0.56, 2.78
	> 75	369	33.3	2.03 [f]	0.98, 4.22
Type of soil[b]	Sand	579	33.5	1.00	-
	Clay	931	24.6	0.88	0.39, 1.99
	Mixed	624	25.5	0.75	0.33, 1.68
Length walking path[b] (m)	< 150	400	40.7	1.56	0.86, 2.84
	150-500	1216	22.5	1.00	-
	> 500	518	28.0	1.32	0.47, 3.71
pH soil[b]	≤ 5.5	1233	29.3	1.00	-
	> 5.5	901	24.5	0.64	0.35, 1.19
Cows trimmed individually between herd trimmings[b] (%)	< 10	727	20.5	1.00	-
	10-20	784	29.0	1.76	0.67, 4.65
	> 20	623	33.1	1.12	0.49, 2.57
Interval between herd trimmings (mo)	< 5.5	328	24.4	0.63	0.23, 1.70
	5.5-7	1068	23.8	1.00	-
	> 7	738	33.6	2.09	1.19, 3.67

[a] rho (farm-level variation) = 10.1%; [b] variable retained because it is a confounder;
[c] slatted floor; [d] slatted floor with manure scraper; [e] solid concrete floor; [f] $P \leq 0.10$.

Table 3. Final multivariable logistic-regression model (with herd included as random effect)[a] for the presence of digital dermatitis at the end of the **housing** period 2000, for 2892 cows of 47 herds from The Netherlands.

Risk factor	Class	Frequency	Prevalence (%)	Odds Ratio	95% CI
Cow-level					
Parity	1	961	31.5	2.06	1.59, 2.67
	2	807	21.2	1.94	1.49, 2.54
	3	502	29.1	1.77	1.32, 2.39
	≥ 4	622	19.6	1.00	-
Herd-level					
Flooring system	SL[c]	1516	28.8	1.00	-
	SL-SCR[d]	734	24.9	0.58[f]	0.32, 1.03
	SCF[e]	642	31.8	1.20	0.70, 2.05
Grazing system[b]	Full	1591	26.4	1.00	-
	Restricted	687	32.3	1.40	0.81, 2.39
	Zero-grazing	614	29.5	0.91	0.47, 1.79
Rearing calves within the dairy cows' accommodation	Yes	1471	24.4	0.61	0.40, 0.94
	No	1421	32.7	1.00	-
Cubicle type	English	896	19.5	0.43	0.26, 0.70
	Legless	728	30.4	1.86[f]	0.98, 3.53
	R	1268	33.7	1.00	-
Length of cubicles (cm)	< 220	695	25.9	0.47	0.27, 0.83
	220-230	1648	31.6	1.00	-
	> 230	549	22.4	0.23	0.11, 0.45
Width of cubicles (cm)	≤ 110	1312	28.3	0.71	0.45, 1.12
	110-115	820	32.5	1.00	-
	> 115	360	20.3	0.50	0.25, 1.00
Thickness of cubicle bedding[b] (cm)	< 5	2485	29.9	1.00	-
	≥ 5	407	19.7	0.64	0.35, 1.16
Step-up concentrate amount (weeks)	< 2	889	33.5	2.07	1.27, 3.36
	2 - 3	1473	26.9	1.00	-
	> 3	530	24.3	1.40	0.74, 2.64
Energy-content roughage[b]	Low	938	27.7	1.31	0.76, 2.27
	Medium	1279	27.2	1.00	-
	Rich	645	31.9	1.35	0.75, 2.44
By-products	Yes	2051	30.5	1.58[f]	0.97, 2.58
	No	841	23.5	1.00	-
Introduction of dry cow into the lactating herd	After calving	634	24.9	1.00	-
	1-14 d before	1131	28.8	2.72	1.49, 4.96
	> 14 d before	1127	30.1	1.78[f]	0.99, 3.21
Dry cows	One group	1239	25.7	1.00	-
	Rest and start	1653	30.6	1.70	1.06, 2.73
Times footbath used each year	≤ 8	1080	26.0	1.00	-
	9-12	806	22.8	1.10	0.59, 2.03
	> 12	1006	35.6	1.75	1.04, 2.96
Purchase of dairy cattle in last year[b]	Yes	734	32.7	1.44	0.82, 2.53
	No	2158	27.0	1.00	-

[a] rho (farm-level variation) = 5.6%; [b] variable retained because it is a confounder;

[c] slatted floor; [d] slatted floor with manure scraper; [e] solid concrete floor; [f] $P \leq 0.10$.

DISCUSSION

Primiparous cows had the greatest odds of DD, similar to other studies (Frankena et al., 1991; Brizzi, 1993; Rodriguez-Lainz et al., 1996; Argaez-Rodriguez et al., 1997; Read and Walker, 1998; Rodriguez-Lainz et al., 1999). First-parity cows are exposed to drastic changes in nutrition, metabolism and also in environment around the time of calving, and therefore they may be more susceptible to acquire DD. The risk decreased steadily with increased parity. There could be two reasons for this result. Affected cows at older age might have a higher culling probability and immunity generally increases with age (Frankena et al. 1991; Blowey et al., 1994; Read and Walker, 1998).

Cows had lower odds when dried-off. This result is in coherence with Murray et al. (2002) who reported a lower DD prevalence in dry cows compared to milking cows. Generally, dry cows are fed a higher proportion of roughage in the diet and as a consequence they excrete more-solid faeces. In this way, dry cows are less exposed to wet and unhygienic flooring conditions caused by liquid slurry than lactating cows.

Moisture conditions and poor foot hygiene are predisposing factors for DD (Blowey and Sharp, 1988; Frankena et al., 1993; Rodriguez-Lainz et al., 1996). The beneficial effect of slatted floor with scraper in the housing study (OR 0.6) can be attributed to a reduction in wet and unhygienic circumstances on the floor by regular removal of manure. The odds for DD on a solid concrete floor (OR 1.2) were marginally higher than on a slatted floor.

Frankena et al. (1991) showed that having only limited access to pasture increased the risk of having DD at the end of the pasture season, as we again found. A considerable part of our study population was housed during the night at the end of the pasture season. The negative effect of housing on the presence of DD has been illustrated by the result that cows housed > 75 days at the end of the pasture season had twofold increased odds for DD (OR 2.0 relative to cows housed ≤ 25 days).

In a British survey of cubicles, poor cubicle conditions were associated with higher prevalence of foot lameness (Faull et al., 1996). The role of lying comfort as a potential measure to prevent DD was confirmed in our study: the odds of DD were decreased when cows had access to longer cubicles (OR 0.2) compared to the standard cubicle length. Nevertheless, no explanation was found why cubicles shorter than the standard length (OR 0.5) gave also lower ORs. The English cubicle (Newton Rigg) was negatively associated to DD, whereas the legless cubicle doubled the odds relative to the R-cubicle; we have no plausible explanation for this result.

A fast rise in concentrate amount after calving (< 2 weeks to maximum amount) appeared to be strongly positively associated (OR 2.1) with DD compared to a medium step up (2-3 weeks). An excessive amount of concentrate shortly after calving might enhance the postnatal imbalance in cows' metabolism. As a result of accompanying higher level of metabolic stress, cows might be more susceptible to diseases (Enevoldsen et al., 1994) and for example, show signs of DD.

In The Netherlands, by-products fed to dairy cattle are mainly residual products coming from the food industry (e.g. brewery, potato-processing factory). Most of these by-products are protein-rich dietary components. The negative effect of by-products might be explained by an imbalance between protein intake fine-tuned at the herd level and a cow's individual need. An excessive protein intake was mentioned before as a potential risk factor for DD (Bargai, 1994).

The use of footbath is a frequently used management practice to treat DD. In a cross-sectional study among 22 dairy farms in southern Chile, farms that used a footbath were less likely to have DD lesions (Rodriguez-Lainz et al., 1996). Conversely, we found a positive association between frequent footbath use and DD presence. This finding was also demonstrated in a case-control study among 57 Californian dairy farms (Rodriguez-Lainz et al., 1996). It is very likely that farmers experiencing a high prevalence of foot problems in their herds use a footbath more frequently to reduce their problems. It must be noted that the efficiency of footbath application is often not optimal, because it is not applied properly (e.g. wrong temperature, dirtied by manure).

A long interval between two herd trimmings (> 7 months) was associated positively with DD (OR 2.0) compared with a medium interval. This emphasises the importance of regular herd trimming in current dairy farming, at least twice a year.

Housing calves and heifers within the dairy cows' accommodation was negatively associated to DD in our study. As stated before, animals introduced to a foreign environment are temporarily in a state of higher susceptibility. Introducing calves at around 1 year of age into the dairy cows' barn provides enough time to adapt to the new housing and associated pathogen environment during the rest of their rearing period. This diminishes a stressful event in heifers in the time prior to calving. Conversely to this explanation, introduction of dry cows into the lactating herd before calving was strongly associated with having DD (OR 2.7 for ≤ 14 days before calving, and 1.8 for > 14 days), relative to introduction immediately after calving. Dry cows were at lower risk for DD and apparently, this effect can be maximised by avoiding contact with lactating cows before calving. Housing dry cows within one group was advantageous compared with dividing dry cows into a rest- and start-up-group. This is difficult to explain.

The farm-level variation was small in both multivariable models. In the pasture period, 10.1% of the total variation was due to between-farm variance, whereas in the housing period this percentage was 5.6.

Keeping in mind that the risk factors identified in present study are only associations based on a cross-sectional study and might not be causal, they may provide some tools to reduce prevalence of DD in a dairy herd.

CONCLUSIONS

First-parity cows and lactating cows were at higher risk. In addition, cows with full access to pasture during the summer, cows housed under drier flooring circumstances (e.g. kept on automatic scraped slatted floor, during the dry period and separated from the lactating herd before calving), cows who have access to long and wide cubicles as well as cows that were raised within the dairy cows' accommodation were at lower risk for developing lesions of DD. Conversely, management routines such as a rapid increase in concentrate amount after calving, feeding by-products, and herd trimming at long intervals were associated with increased odds.

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Chapter 4

Risk Factors for Interdigital Dermatitis and Heel Erosion in Dairy Cows Kept in Cubicle Houses in The Netherlands

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ABSTRACT

Risk factors concerning both the pasture and housing seasons for interdigital dermatitis and heel-horn erosion (IDHE) were studied in dairy cows in a cross-sectional study in The Netherlands. The study population included 2326 cows (41 herds) and 2751 cows (46 herds) for the pasture and housing seasons, respectively. Of these animals, 545 (23%) showed serious lesions of IDHE (stage 2 and 3) at the end of the pasture season and 1269 (46%) during housing. Logistic regression of the pasture study indicated that increased parity, solid concrete floor, restricted grazing time, and herd trimming at long intervals were associated with an increased odds of IDHE, while dry cows and lactating cows within 30 days after calving as well as cows on a slatted floor with manure scraper, and grassland with mixed type of soil were associated with lower odds. In the housing study, odds of IDHE increased with parity, administering low- or medium-energy roughage, introduction of dry cows into the lactating herd > 2 weeks before calving, and infrequent use of footbath. The presence of long cubicles, knee-bumpers installed in cubicles as well as rearing calves and heifers within the dairy cows' accommodation decreased the odds of IDHE.

Abbreviation key: **IDHE** = interdigital dermatitis and heel erosion

INTRODUCTION

Interdigital dermatitis and heel-horn erosion are perhaps the most common digital lesions in dairy cattle (Enevoldsen et al., 1991; Philipot et al., 1994b; Somers et al., 2003). Because of their explicit interrelationship (Toussaint Raven et al., 1985; Philipot et al., 1994a; Manske et al., 2002), both diseases can be pooled together as one condition: interdigital dermatitis/heel erosion (IDHE). The course of IDHE is characterised by two stages. Initially, an infection of Dichelobactor (Bacteroides) nodosus (possibly accompanied by Fusobacterium necrophorum) results in an inflammation of the interdigital skin. Subsequently (in chronic cases), the infection gives rise to a superficial erosion of the heel horn (Peterse, 1985; Bergsten, 1997). Disturbance in the growing process of bulb horn can cause deep clefts and even fissures at the heel. The seriousness of heel erosion depends on environmental conditions (e.g. housing, feeding, management) and the presence of secondary invaders, representing a multifactorial aetiology. The importance of herd-level factors influencing prevalence is supported by the substantial variation in IDHE herd prevalence found in two epidemiological studies, varying between 0 and 91% on 101 Swedish dairy farms (Manske et al., 2002) and between 2 and 93% on 47 Dutch farms with cubicle houses (Somers et al., 2003).

Some studies describe cubicle houses to be a risk factor for IDHE compared to tie-stalls (Thysen, 1987), whereas others have found no association between housing system and IDHE lesions in hind claws (Bergsten and Herlin, 1996). Straw-yard systems were associated with lower prevalence of IDHE, relative to cubicle houses (Somers et al., 2003). The concrete floor is also an important factor influencing the prevalence of IDHE. A Danish study demonstrated that the condition occurred more frequently in cows housed on solid concrete floors than on slatted floors (Thysen, 1987). Other predisposing factors include housing instead of pasturing, moist and dirty floor conditions, dietary composition, herd size, age and stage of lactation (Peterse, 1980; Blowey and Sharp, 1988; Manson and Leaver, 1988a, 1988b; Enevoldsen et al., 1991; Frankena et al., 1991; Livesey et al., 1998)

Most IDHE cases are relatively mild (stage 1) and therefore the condition has not explicitly been associated with lameness (Toussaint Raven and Cornelisse, 1971; Blowey and Sharp, 1988; Manske et al., 2002). However, the disease can become more severe (stage 2 and 3) and predispose animals to other claw diseases such as digital dermatitis, interdigital phlegmon and sole ulcer (Blowey, 1994). Digital dermatitis is a disease of growing concern, because it is commonly associated with pain and discomfort, lameness, and subsequent impaired performance (Nutter and Moffit, 1990; Read et al., 1992; Brizzi, 1993; Rodriguez-Lainz et al., 1996; Argaez-Rodriguez et al., 1997; Greenough and Weaver, 1997; Read and Walker, 1998).

We performed an epidemiological study comparing claw health in Dutch dairy cattle on different flooring systems (Somers et al., 2003). One of the recorded claw disorders was IDHE. Our aim in these analyses was to quantify the effects of several cow- and herd-related variables on the presence of IDHE during the pasture and housing periods in dairy cows kept in cubicle-housing systems.

MATERIALS AND METHODS

Study design and data collection

Data were from dairy herds in The Netherlands that participated in the previously reported claw health study (Somers et al., 2003). Detailed information about the study herds, inclusion criteria and the procedure in claw inspections is described in a parallel risk study on digital dermatitis (see Chapter 3). In short, hind hooves of cows were examined for lesions of IDHE and other claw disorders during herd-trimming visits between September 1999 and June 2000. IDHE was recorded on a scale of 0 to 3, based on the definitions of Peterse (1980): 0, no signs; 1, slight pock marking and/or superficial horn defects in the axial surface of the bulb; 2, some big fissures or grooves in the horn of the bulb and / or sole, not extending to the corium; 3, disappearance of heel horn and or deep defects in the horn of bulb or sole, extending to the corium. For the analysis of risk factors, a cow was scored IDHE-positive when she had IDHE lesions stage 2 or 3; superficial IDHE (stage 1) was handled as IDHE-negative. A similar definition for IDHE-cases has been used in a recently published prevalence study in Swedish dairy herds (Manske et al., 2002).

To make distinguish between 'summer' and 'winter' conditions, the observation period was divided into a pasture and housing study. The pasture study included cows that were ≥ 50 days at pasture at the time of herd trimming, or ≤ 15 days housed when the pasture season had finished. Cows included in the housing study were housed for ≥ 50 days, or ≤ 15 days at pasture at the end of the housing season. Data on potential cow-level and herd-level risk factors were obtained using computerised records, a questionnaire administered to the farmer, and by on-farm inspections. Detailed information on the broad range of tested exposure variables (based on literature surveillance) and its categories has been described elsewhere (see Chapter 3).

Statistical analysis

Potential risk factors for IDHE concerning the pasture and housing study were tested separately in random-effects models using logistic regression. The model-building process was identical to the risk study on digital dermatitis (see Chapter 3). First, a primary screening was performed to identify exposure variables related to IDHE (chi-square test, $P < 0.20$). Multivariable models were obtained using a backwards-elimination procedure in SAS (SAS Institute Inc., 1996) until only variables (or group of dummy variables) with $P < 0.05$ remained. Potential confounders re-entered the model. No interactions were tested. To take clustering of animals within herds into account, both resulting models were re-run including herd as random effect using STATA (Stata Corporation, 1999). Because some of the *P*-values were altered substantially in the random-effects model, the backwards-elimination procedure was used once again until only variables with $P < 0.10$ or confounders remained. Results were expressed as odds ratios (OR) and 95% confidence intervals (CI).

RESULTS

Cow prevalence

A total of 2326 cows (41 herds) and 2751 cows (46 herds) were used for the risk-factor analyses of the pasture and housing period, respectively. The overall cow prevalence for serious IDHE (stage 2 and 3) was 23.4% at the end of the pasture period and 46.1% in the housing study.

Pasture study

In univariable analysis, 12 exposure variables were related to IDHE (not presented). When adjusting for colinearity, the variable region was dropped in favour of type of soil. Adjusted ORs and CIs of variables remaining in the final random-effects model are given in Table 1. Six variables (or group of dummy variables) retained significance in the random-effects model, and two variables were considered confounders.

Table 1. Results of the final logistic-regression model (with herd as random effect)[a] for the occurrence of serious interdigital dermatitis and heel erosion at the end of the **pasture** period 1999, for 2326 cows of 41 Dutch dairy herds.

Risk factor	Class	Frequency	Prevalence (%)	Odds ratio	95% CI
Cow level:					
Parity	1	747	16.3	1.00	-
	2	618	21.8	1.31[f]	0.98, 1.76
	3	424	30.4	2.34	1.72, 3.18
	≥ 4	537	29.6	2.43	1.82, 3.26
Stage of lactation (d)	0 - 30	208	16.3	0.52	0.35, 0.79
	31 - 70	309	21.7	0.83	0.60, 1.14
	> 70	1498	25.8	1.00	-
	Dried-off	311	18.6	0.62	0.44, 0.86
Herd level:					
Flooring system	SL[c]	1101	20.8	1.00	-
	SL-SCR[d]	357	14.6	0.27	0.11, 0.65
	SCF[e]	868	30.4	2.13	1.30, 3.49
Grazing system	Full	1863	21.3	1.00	-
	Restricted	463	32.2	3.49	1.67, 7.29
Type of soil	Sand	617	28.7	1.00	-
	Clay	995	21.9	0.64	0.33, 1.25
	Mixed	714	21.0	0.48	0.26, 0.88
Length walking path[b] (m)	< 150	678	27.1	1.12	0.67, 1.87
	150 - 500	1031	19.0	1.00	-
	> 500	617	26.7	1.58	0.91, 2.75
Times footbath used	≤ 2	1092	22.9	0.86	0.48, 1.54
during pasture period[b]	3 - 5	434	21.2	1.00	-
	> 5	800	25.4	0.68	0.35, 1.33
Interval herd trimming	< 5.5	563	23.1	0.86	0.47, 1.59
(mo)	5.5 - 7	956	19.1	1.00	-
	> 7	807	28.8	1.78	1.09, 2.91

[a] rho (farm-level variation) = 7.5%; [b] variable retained because it is a confounder

[c] slatted floor; [d] slatted floor with manure scraper; [e] solid concrete floor

[f] $P \leq 0.10$.

Table 2. Results of the final logistic-regression model (with herd as random effect)[a] for the occurrence of serious interdigital dermatitis and heel erosion during the **housing** period 2000, for 2751 cows of 46 Dutch dairy herds.

Risk factor	Class	Frequency	Prevalence (%)	Odds ratio	95% CI
Cow level:					
Parity	1	903	31.9	1.00	-
	2	780	46.9	2.10	1.69, 2.61
	3	480	54.2	3.26	2.52, 4.21
	≥ 4	588	60.4	3.98	3.12, 5.08
Herd level:					
Flooring system	SL[c]	1478	47.8	1.00	-
	SL-SCR[d]	709	37.9	0.62	0.32, 1.19
	SCF[e]	564	52.0	1.26	0.69, 2.28
Herd size[b]	≤ 50	326	53.7	1.00	-
	51-75	1439	42.5	1.47	0.76, 2.84
	> 75	986	49.0	1.04	0.50, 2.18
Rearing calves within the dairy cows' accommodation	Yes	1366	40.9	0.59	0.35, 0.98
	No	1385	51.3	1.00	-
Length of cubicles (cm)	< 220	623	40.0	0.65	0.38, 1.09
	220-230	1591	51.1	1.00	-
	> 230	537	38.5	0.49[f]	0.23, 1.06
Knee-bumpers in cubicles	Yes	1289	37.1	0.51	0.32, 0.83
	No	1462	54.1	1.00	-
Step up concentrate amount[b] (weeks)	< 2	816	46.2	1.00	-
	2 - 3	1422	47.6	0.95	0.54, 1.65
	> 3	513	41.9	1.38	0.70, 2.72
Energy-content maize[b]	Low	920	51.5	1.68	0.89, 3.19
	Medium	1058	44.6	1.02	0.53, 1.98
	High	773	41.8	1.00	-
Energy-content roughage	Low	863	54.5	2.10	1.19, 3.69
	Medium	1261	41.7	2.23	1.21, 4.08
	High	627	43.5	1.00	-
Introduction of dry cows into the lactating herd	After calving	563	43.0	1.00	-
	1-14 d before	1086	38.1	1.30	0.71, 2.38
	> 14 d before	1102	55.6	3.12	1.69, 5.75
Dry cows	One group	1147	45.1	1.00	-
	Rest and start	1604	46.9	2.46	1.51, 4.01
Times footbath used each year	≤ 8	988	47.7	1.51	0.93, 2.45
	9-12	788	43.7	0.91	0.51, 1.98
	> 12	975	46.6	1.00	-
Use of footbath during dry period	Yes	634	56.6	2.33	1.36, 3.98
	No	2117	43.0	1.00	-
Purchase of dairy cattle in last year[f]	Yes	710	42.4	0.69	0.40, 1.18
	No	2041	47.4	1.00	-

[a] rho (farm-level variation) = 7.2%; [b] variable retained because it is a confounder

[c] slatted floor; [d] slatted floor with manure scraper; [e] solid concrete floor

[f] $P \leq 0.10$.

Housing study

In the primary screening test, 34 exposure variables were associated with IDHE during housing (not presented). After testing for colinearity, eight variables (i.e. thickness of cubicle bedding, cubicle-end bumper, protein-content roughage, indigestible protein-content roughage, maximum concentrate dose, number of cows trimmed individually between two herd trimmings, access to pasture at the time of herd trimming, and regular cleaning of the barn) were dropped in favour of the variables width of cubicles, knee-bumper, energy-content roughage, maize amount lactating cows, herd size, herd size, grazing system, and grazing system, respectively. 14 variables were significant when no random effect was included in the multivariable model. In the random-effects model, nine variables were significant; the remaining variables were confounders. The final random-effects model for the housing study is in Table 2.

DISCUSSION

Exposure of claws to faeces on the floor and the subsequent contamination is a plausible explanation for the doubling in IDHE affected cows during the housing season (46% vs. 23% at the end of the pasture season). The protective effect of grazing on IDHE has been demonstrated previously (Peterse, 1980; Frankena et al., 1991). An increase in IDHE prevalence as the housing season progresses points out the adverse effect of housing (Frankena et al., 1991; Bergsten and Pettersson, 1992; Offer et al., 2000). In the literature, cow prevalences for serious IDHE during housing varied from 12% (Philipot et al., 1994b), 16% (Enevoldsen et al., 1991), 32% (Smits et al., 1992), 41% (Manske et al., 2002), to 53% (Frankena et al., 1991). As classification of IDHE and breeds were similar, differences in environmental conditions might account for the between-study variation in IDHE prevalence.

IDHE is a condition positively associated with parity, also in the literature (Enevoldsen et al., 1991; Frankena et al., 1991; Smits et al., 1992). That primiparous cows had the lowest odds is in agreement with similar risk studies in nulliparous cows, where no cases of serious IDHE were found among calves between 3 and 12 months of age (Bradley et al., 1989; Frankena et al., 1993). With increasing age, mild stages of IDHE (i.e. superficial) decrease in prevalence in favour of more-severe stages. A long-term effect of housing corresponds with a pronounced degradation of heel horn at older age (Enevoldsen et al., 1991).

The pasture model's lower odds for cows within 30 days after calving and dry cows partly agrees with Livesey et al. (1998), who reported a significant increase in IDHE level in heifers at 12 weeks post partum relative to the prepartum period. Offer et al. (2001) reported an increase in severity of heel erosion in heifers with time after calving. The beneficial effect of the dry period may be ascribed to drier flooring circumstances in dry cows. Higher roughage intake and no concentrates result in a higher consistency of faeces, and subsequently a reduction of the detrimental liquid slurry on the floor. In addition, the lower prevalence around calving might be partly attributed to claw-care management during drying-off, because some dairy farmers perform individual claw trimming of their cows at the start of the dry period. (The idea is that claw diseases abate during the dry period, and this can be enhanced by claw trimming at that time and if necessary an appropriate therapy.) However, the role of claw trimming in the dry period as a suitable intervention strategy was not investigated in our study because detailed information on this item was not available. In the housing model, again dry cows had lower odds of IDHE.

Cows housed on a slatted floor with manure scraper had lower odds than those on a standard slatted floor, which agreed with Swedish studies (Bergsten and Pettersson, 1992; Hultgren and Bergsten, 2001). Wet and unhygienic floor conditions result in softening of the digital horn, making the claw capsule more susceptible to abrasion and bacterial invasion (Greenough et al., 1981). By frequent removal of manure and urine, automatically scraped slatted floors reduce the negative effects of a wet and unhygienic claw environment. Surprisingly to us, the prevention was found in the pasture (OR 0.3, $P < 0.01$), but not in the housing model (OR 0.6, $P = 0.15$). During housing, cows are exposed continuously to an unfavourable floor environment. The pasture model revealed increased odds for cows on solid concrete floors (OR 2.1) compared to slatted floors – confirming Thysen (1987), whereas this association was less evident during housing (OR 1.3). Therefore, we suspect that the detrimental effects of concrete flooring on the claw capsule accumulate during housing in a way that advantageous effects of flooring characteristics are fading as the housing season passes. An exception to this hypothesis is the straw-yard system, in which the beneficial effect of a dry floor surface (i.e. deep-litter area) holds during housing (Somers et al., 2003).

IDHE was highly associated with restricted grazing time during the summer (i.e. indoors at night; OR 3.5), following from the protective effect of pasture. There could be two biological reasons for this finding. First, cows in a full-grazing system are less exposed to the unfavourable housing environment than those in a restricted-grazing system. Second, minor lesions of IDHE might heal spontaneously when cows are on pasture (Peterse, 1985; Toussaint Raven et al., 1985; Maton, 1987), and cows having full access to pasture are more able taking advantage of the curative effect. The indicated lower risk for cows in regions with grassland with a mixed type of soil (e.g. clay and sand) to develop IDHE at pasture, compared to those on sandy soil, might be due to differences in soil properties. However, soil was highly correlated with region ($r = |0.64|$), and it might be that cows in regions with mixed soil (i.e. mainly western part of The Netherlands) experience other beneficial circumstances associated with that region (e.g. groundwater level).

There were decreased odds for IDHE in farms with long cubicles (OR 0.5; $P = 0.07$). The importance of good cubicle conditions with respect to claw health has been underlined previously (Faull et al., 1996; see also Chapter 3). This could be a direct effect of increased lying times arising from good lying comfort, in favour of shorter standing times on the adverse concrete flooring environment. Knee- and end-bumpers are installed in cubicles to facilitate standing up and lying down, and in case sawdust bedding is provided. Such an improvement of cubicle conditions might explain why according to our results the presence of a knee-gilder in the front of cubicles was negatively associated to IDHE.

Experimental studies tell us that nutritional factors are influences of claw health in dairy cattle. Type and quantity of concentrate in the diet (Peterse et al., 1984; Manson and Leaver, 1989; Livesey et al., 1998), high protein intake (Manson and Leaver, 1988b), and wetness of grass silage (Clarkson et al., 1993) are associated with increased lameness incidence. One mediating factor might be the consistency of faeces and associated wetness of floor surface. Recently, Offer et al. (2001) concluded that feeding grass silage resulted more frequently in disturbed locomotion and more-severe IDHE in heifers compared to a mixed hay/concentrate diet. Less information on dietary exposure variables is available from dairy herds monitored in epidemiological studies. Low- and medium-energy roughage were identified as important risk factors (Table 2). We note that the effect of energy supply might be masked by differences in farm management (e.g. grassland management).

An abrupt change in environment around first calving is an important stressor and plays a substantial role in the development of claw lesions. The reduced odds for IDHE when calves and heifers were raised within the dairy cows' accommodation (Table 2) might be explained by lower stress in case of environmental adaptation at younger age.

Dividing dry cows into a rest- and start-up-group (OR 2.5) as well as introduction of dry cows into the lactating herd > 2 weeks before calving (OR 3.1) were positively associated with IDHE, which is in accordance with their effects on digital dermatitis (see Chapter 3). For some reason, beneficial effects associated with the dry period deteriorate as soon as dry cows are exposed to more adverse conditions in the lactating herd (e.g. wetter floor circumstances as a consequence of lower consistency of faeces, less hygiene). We note that in some herds, dry cows in a start-up-group are being housed among lactating cows.

Both the pasture and housing models revealed that claw-care management is important in reducing IDHE. In the pasture model, herd trimming at long intervals (defined as > 7 months) was strongly related to IDHE (OR 1.8). In The Netherlands, herd trimming twice a year is common. Claw trimming is the only treatment for serious IDHE, although it has been suggested that minor lesions of IDHE can heal spontaneously (either at pasture or at the end of lactation) (Peterse, 1985; Toussaint Raven et al., 1985; Maton, 1987). We are unaware of literature describing the development of IDHE stages in-depth, and therefore, we cannot indicate within what time period in general a cow develops serious IDHE after having been trimmed. Given that no difference was found between a short and medium interval of herd trimming, severe stages of IDHE seem to develop gradually. Infrequent use of footbath was identified as a risk factor for IDHE and this corresponds well to the literature. Footbaths containing formaline are recognised as an effective therapy against

IDHE (Toussaint Raven et al., 1985; Arkins et al., 1986; Bergsten, 1997). In our analyses, no distinction was made between types of solution - only frequency of use was classified. The increased risk on farms that use footbaths also in dry cows is contrary to the above hypothesis. However, these farms also have higher prevalences of digital dermatitis (cow-prevalence rate = 37% vs. 26% on farms without footbath in dry cows), and hence might apply also footbathing on their dry cows.

The farm-level variation was small in both random-effects multivariable models. The total variation due to between-farm variance was 7.5% and 7.2% in the pasture and housing model, respectively.

CONCLUSIONS

Our analyses showed that aged cows, cows on farms with a solid concrete floor, restricted grazing time, low energy supply in the diet, and early introduction of dry cows into the lactating herd had increased odds of serious lesions of IDHE. Good claw environment and claw-care management are essential in reducing IDHE. Odds-lowering factors included full pasturing in the summer accompanied by automatically-scraped slatted floors and long cubicles with knee-bumpers. Good claw management is characterised by frequent use of footbath in lactating cows, herd trimming at least each six months, whether or not accompanied by individual trimming of dry cows.

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Chapter 5

Development of Claw Traits and Claw Lesions in Dairy Cows Kept on Different Floor Systems

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ABSTRACT

Several claw shape measurements, horn hardness, and horn growth and wear were recorded on 12 dairy herds at monthly intervals to investigate the effect of floor type on these traits and the changes over time. Herds were either housed on a slatted floor (SL), solid concrete floor (SC), grooved floor (GR), or in a straw yard (SY). Per farm 20 cows were selected randomly but stratified by parity. Information on claw traits was recorded on right lateral hind claws between October 2002 and May 2003. In addition, lesion development of interdigital dermatitis and heel erosion (IDHE) and digital dermatitis (DD) was studied in both rear feet. No differences in claw traits were found between groups of animals on different floor types, with the exception of claw angle. Claw angles were smallest in SY, and claws on SC were steeper than those on SL and GR. The study provided no evidence that floor-related differences in claw lesions were related to differences in horn growth and wear and resulting claw shape.

Lesions of IDHE developed gradually over time and no effect of floor type was found. Cows in SY had the lowest lesion score for DD, while cows on SL had significantly less DD than cows on SC and GR. Incidence of DD fluctuated strongly in time. Development of different stages of DD has been monitored in-depth. Both early and healed stages were rather changeable and often turned into other disease stages. Classical ulcerative lesions (stage M2) persisted for a long period, while 20% of the initially unaffected claws showed active lesions of DD within five months. M2 lesions generally did not cure effectively with claw trimming and frequent use of footbath, resulting in a poor prognosis for recovering.

Abbreviation key: **DD** = digital dermatitis, **GR** = grooved floor, **IDHE** = interdigital dermatitis and heel erosion, **SC** = solid concrete floor, **SL** = slatted floor, **SY** = straw yard.

INTRODUCTION

Claw lesions and lameness are of major concern in dairy farming. A healthy locomotor apparatus is a crucial element for normal animal behaviour and social activity. In general, claw and locomotor problems have become more serious since the introduction of loose-housing systems. Although improvements in dairy farming on housing design and nutrition have been made, and farmers do recognise the importance of good claw-care management (e.g. regular herd trimming, use of footbath), incidences of claw lesions and lameness remain at a high level (Murray et al., 1996; Hedges et al., 2001). In extended studies, the number of dairy cows showing claw lesions has recently been estimated at 70 to 80 percent (Manske et al., 2002; Somers et al., 2003).

It is believed that many claw lesions are the result of poor horn quality (Greenough, 1991) and overgrown claws (Russell et al., 1982; Distl et al., 1984). The bovine claw capsule is in a continuous process of turnover and in a normal situation, horn growth and wear occur at approximately equal rates (Vermunt and Greenough, 1995). However, when animals are housed on concrete floors, claw shape changes. Horn growth is accelerated by load bearing on hard surfaces (Bergsten and Stranberg, 1990; Vermunt, 1996) and the abrasiveness of concrete induces increased wear and tear (Murphy and Hannan, 1987). Prolonged upsetting of horn production together with unsatisfactory resistance of claw horn towards adverse floor conditions may result in malformation of the claw. This may threaten the locomotor apparatus as it is generally accepted that strongly overgrown and malformed claws are vulnerable to both mechanical injury and penetration by infectious agents.

In modern dairy farms, cows are predominantly kept in loose houses with concrete walking alleys. Epidemiology has demonstrated that housing on concrete is associated with adverse claw health (Russell et al., 1982; Frankena et al., 1991; Albright, 1995), and the major part of claw lesions occurs in lateral hind claws. Overloading of the claw has been suggested as a primary cause given that biomechanical experiments indicated that, while standing on concrete, weight bearing in hind limbs is mainly subjected to the lateral claw (Toussaint-Raven, 1973; Ossent et al., 1987). Moreover, total load and pressures exerted during walking were twice as high as while standing (Scott, 1988; Van der Tol et al., 2003). A positive correlation between a prolonged stay on concrete passageways and an increased risk for developing claw horn lesions has also been established (Bergsten and Frank, 1996; Livesey et al., 1998). Mechanical stress applied to the bovine claw and limb is considerably reduced on a soft surface. In this respect it makes sense that straw-yard systems proved to be more favourable with respect to claw health than cubicle houses (Hughes et al., 1997; Webster, 2001; Somers et al., 2003). Moreover, it has been shown that presence and severeness of claw lesions decreases on rubber floors (Hultgren and Bergsten, 2001; Benz, 2002). The abrasiveness of concrete and the degree of hygiene and moisture content on the floor are also important elements in the aetiology of claw disorders (Blowey and Sharp, 1988; Frankena et al., 1993; Vokey et al., 2001). For both economic and management reasons, dairy cows in the Netherlands are increasingly housed, also during the summer period. This makes it of primary importance to provide floor surfaces that ensure healthy, normally shaped claws, and unrestricted movements of an animal.

In a previous cross-sectional study, we showed that infectious claw disorders and haemorrhages of the sole are predominantly present in Dutch dairy cows and that their appearance was highly correlated with type of flooring (Somers et al., 2003). Some of the infectious lesions (i.e. digital dermatitis, severe heel erosion) are of major concern for animal welfare because they are long-lasting, associated with pain and discomfort, and may result in lameness. Hence, risk studies were initiated to come up with factors and conditions by which farmers may manage towards an improved situation regarding those lesions (see Chapter 3 and 4). But additional information on the role of flooring in the disease process is needed to develop a more radical solution to the problem. Therefore, we performed an in-depth monitoring of claw traits and development of important claw lesions (i.e. interdigital dermatitis, heel erosion, and digital dermatitis) in dairy cows kept on various flooring systems. This paper describes a longitudinal study to investigate the effect of floor design on 1) horn growth and changes in physical characteristics of the claw and 2) the development of some important infectious claw lesions.

MATERIALS AND METHODS

Study population and design

The study was conducted on 12 commercial dairy farms in the Netherlands. First, farms were selected from 86 dairy herds that participated in an earlier cross-sectional survey (Somers et al., 2003). Farms with an average level of claw problems were preferentially selected. In addition, farms had to meet the selection criteria of herd size > 35 cows, Holstein-Friesian as the breed, pasturing in the summer, and the farmer's willingness to collaborate on the study. Nine herds were selected, of whom three had a slatted floor (**SL**), three a solid concrete floor (**SC**), and another three had a straw-yard system (**SY**). At the time of study preparation, the Dutch government legislated for ammonia emission reduction in case of renovation or new development of dairy livestock buildings. The grooved floor (**GR**) (consisting of flat concrete floor elements with grooves right-angled to the span of the floor elements; Swierstra et al., 1997) was one of the accredited emission-reducing floor systems. To anticipate the new housing legislation, claw health data were recorded in 10 herds kept on GR and out of those, three herds were selected to join the present study.

Per farm, 20 cows were selected randomly but stratified by parity (1, 2, 3, and ≥ 4). We tried to include equal numbers of animals within each parity class. However, depending on herd's age distribution, a higher proportion of first and second parity cows was selected in favour of older cows. In addition, animal selection was based on cow-lactation index (i.e. corrected rating of individual yield performance compared to the overall herd performance set at value 100) between 80 and 110 at the latest milking record and farmer's expectation that an animal was not culled within the coming year. Data for the selected herds are given in Table 1. The groups of animals on the different floor systems were quite comparable with regard to average lactation number and 305-DIM yield. The smaller herd size in SY is due to a rather labour-intensive management and is typical for SY farms in The Netherlands (Somers et al., 2003). Cows between floor systems were evenly distributed over stages of lactation (<60, 60-120, >120 days), except for a higher proportion of pre-top cows in the group of GR.

Data collection on claw inspections started at the beginning of the housing season and farms were visited at monthly intervals between October 2002 and May 2003. Claws of all cows were trimmed two weeks prior to the first claw inspection by professionals according to the 'Dutch trimming method' (Toussaint-Raven et al., 1985). Heel horn damage was repaired and claw shape properly restored. Doing so, we assumed claws of cows to be in a comparable state at start.

Table 1. Average figures of the selected cows on each floor type, regarding lactation number, stage of lactation (% cows), 305-DIM yield, and herd size at the start of the longitudinal study (SL = slatted floor; SC = solid concrete floor; GR = grooved floor; SY = straw yard).

	SL	SC	GR	SY
Lactation no.	2.44	2.43	2.41	2.48
Stage of lactation:				
- 0-60 d	21	17	30	19
- 60-120 d	13	16	15	13
- >120 d	66	67	55	68
305-DIM yield (kg)	8700	8300	9000	8000
Herd size	57	61	62	42

Claw traits

At each farm visit, data on claw shape, horn hardness, and growth and wear were recorded from the right lateral hind claw. The first author made all observations. Prior to inspection, the claw was brushed and caked manure removed. Detailed measurements were performed to describe claw shape as reviewed by Vermunt and Greenough (1995) (see Figure 1): claw angle, toe length, heel depth, claw height, diagonal, and claw width. A cross was made at the dorsal region of the abaxial wall to measure horn growth and wear. Distances were measured between 1) the mark and the coronal boundary and 2) the mark and the lower edge of the claw. Changes in the distances between two measures were used to calculate growth and wear rates. Monthly rates of growth and wear (mm per 30 days) were obtained after a correction for number of days between two measures. Horn hardness was recorded using a Shore-A-meter as described by Manson and Leaver (1988). This device measures the degree of resistance of claw horn against the penetration of a spring-loaded probe. The penetration depth inwards the measuring instrument increases with increasing hardness of the material tested. Measurements were taken in triplicate each time at four locations within the claw, namely the centre of the heel bulb, the sole, the toe, and the outer wall. Hardness data were averaged for each site.

Claw lesions

Claws of both hind legs were examined for claw lesions. Interdigital dermatitis and heel erosion (**IDHE**) were assessed together for severity and extent on a scale of 0 to 4 (0 = heel horn intact; 1 = slight defect of the horn integrity, pits or small fissures; 2 = V-shaped fissures or circular craters, extending small area of the heel; 3 = V-shaped fissures or circular craters, extending entire heel; 4 = profound fissures or craters, extending to the corium of the heel). Digital dermatitis (**DD**) was classified according to the system by Döpfer (1994). The system includes classes M1 – M5 and is well-suited to describe the development of DD through time: M1 = early stage with a circumscribed granulomatous area, lesion 0.5 to 2 cm in diameter; M2 = classical ulceration, lesion more than 2 cm in diameter; M3 = healing lesion covered by a scab, post therapy; M4 = skin alterations due to former M1 or M2 lesion; M5 = no lesion, no skin abnormalities.

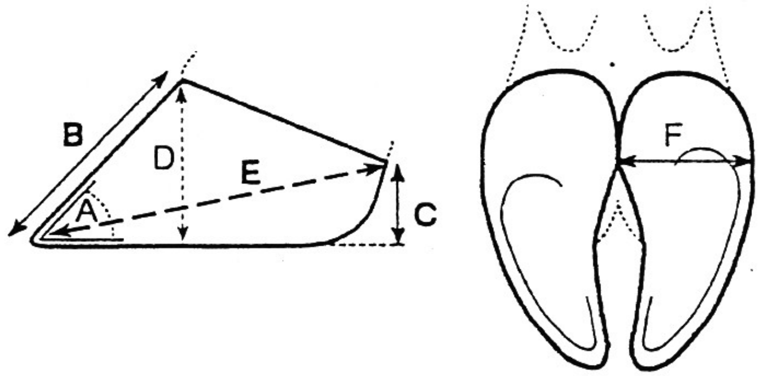

Figure 1. Illustration of various claw traits measured at right lateral hind claws to describe claw shape (by Vermunt and Greenough, 1995): A = claw angle; B = toe length; C= heel depth; D = claw height; E = diagonal; F = claw width.

Statistical analyses

Claws were trimmed at the beginning of the study. In some herds the next trimming event occurred five months later. Data on claw shape, horn hardness, and IDHE are strongly influenced by claw trimming. Therefore, only recordings between 2 and 18 weeks after trimming were considered eligible for analysis. Conversely, rates of horn growth and wear and lesions of DD are affected less directly by trimming. Therefore, data on these variables recorded throughout the entire study period were used in the analysis, regardless of any subsequent trimming.

The maximum IDHE lesion score for an animal was 8 (score 4 in both hind legs). Preceding the analysis of DD lesion scores, categories M3, M4, and M5 (healing stages or absent) were reclassified into score 0, whereas M1 and M2 (active lesions) received scores 1 and 2, respectively. The maximum lesion score for DD was then 4 (M2 in both legs).

Repeated data of individual animals (i.e., claw traits and lesions) were analysed as a split-plot design using the general linear models procedure of SAS (1996). The statistical model included the fixed effects of Floor (SL, SC, GR, or SY), Time (monthly interval), and Floor x Time interaction, the random effect of herd nested within floor type, and the residual error. The main effect of floor type was tested using the mean square of herd nested within floor type as the error term. All other effects were tested using the residual mean square as the error term. Residuals were checked for normality using PROC UNIVARIATE. This condition was fulfilled and the performed analysis was considered legitimate. When a significant effect ($P < 0.10$) for Floor was found, least square means were evaluated and *P*-values were adjusted for multiple comparisons using the Bonferroni correction. Paired samples t-tests were used to assess differences in horn growth and wear associated with claw trimming and the turnover from pasture to housing. Differences were considered to be significant at $P < 0.05$ unless otherwise stated.

RESULTS

Claw traits

Least square means for claw shape measurements, horn hardness and horn growth and wear by floor type are given in Table 2. There were no significant differences in claw shape between the four floor types, except for claw angle ($P = 0.03$). Claw angle was by far the smallest in SY, and claw angles on SC were higher (steeper claws) than those on SL and GR. All claw shape measurements increased with time and there was no interaction between floor and time, with the exception of heel depth.

Table 2. Least square means (±S.E.M.) for claw shape measurements, horn hardness, and horn growth and wear by floor type (SL = slatted floor; SC = solid concrete floor; GR = grooved floor; SY = straw yard). Data were recorded at 240 right lateral hind claws at five monthly measurements after claw trimming.

	FLOOR TYPE				P-VALUES		
	SL	SC	GR	SY	Floor Type	Time	Interaction
Claw angle[1]	46.1±0.26[b]	47.8±0.29[c]	46.6±0.27[b]	42.5±0.33[a]	0.03	0.01	NS
Toe length[2]	8.0±0.03	7.8±0.03	7.9±0.03	8.0±0.04	NS	0.01	NS
Claw width[2]	5.7±0.02	5.8±0.02	5.7±0.02	5.5±0.02	NS	0.01	NS
Claw diagonal[2]	13.6±0.04	13.7±0.05	13.8±0.04	13.7±0.05	NS	0.03	NS
Claw height[2]	6.8±0.03	6.7±0.03	6.8±0.03	6.6±0.03	NS	0.01	NS
Heel depth[2]	4.6±0.03	4.6±0.04	4.6±0.03	4.3±0.04	NS	0.01	0.01
Hardness[3]:							
- Bulb	37.8±0.35	36.6±0.39	36.3±0.36	38.9±0.44	NS	0.01	NS
- Sole	82.4±0.30	82.6±0.34	82.9±0.31	84.0±0.38	NS	NS	0.03
- Toe	89.2±0.16	88.1±0.18	89.9±0.17	90.4±0.20	NS	0.01	0.01
- Wall	92.8±0.14	93.1±0.15	92.6±0.14	92.7±0.17	NS	0.01	0.01
Growth[4]	5.3±0.13	5.4±0.14	4.9±0.13	4.8±0.14	NS	0.01	0.01
Wear[4]	2.9±0.09	2.8±0.09	2.7±0.08	2.3±0.09	NS	NS	0.01
Net growth[4]	2.4±0.14	2.5±0.16	2.3±0.14	2.5±0.16	NS	0.01	0.01

Values with different superscripts differ significantly ($P < 0.05$).

[1] degrees; [2] cm

[3] Shore-A units, 0-100; [4] mm/month

Table 3. Changes in least square means for claw shape measurements with weeks after claw trimming recorded at 240 right lateral hind claws. Data on claw angle and heel depth are presented by floor type because of interaction between time and floor type (SL = slatted floor; SC = solid concrete floor; GR = grooved floor; SY = straw yard).

	Week 2	Week 6	Week 10	Week 14	Week 18
Claw angle (^{0}):					
- SL	44.3	45.1	45.9	46.8	48.5
- SC	45.4	46.5	47.7	49.4	49.8
- GR	44.2	46.4	46.2	47.6	48.6
- SY	41.2	42.4	42.5	43.0	43.2
Toe length (cm)	7.6	7.8	8.0	8.1	8.2
Claw width (cm)	5.6	5.6	5.7	5.7	5.7
Claw diagonal (cm)	13.5	13.7	13.7	13.8	13.7
Claw height (cm)	6.4	6.6	6.7	6.9	6.9
Heel depth (cm):					
- SL	4.3	4.4	4.6	4.8	4.9
- SC	4.2	4.6	4.7	4.7	4.6
- GR	4.1	4.5	4.6	4.8	5.0
- SY	4.0	4.2	4.3	4.2	4.5

Changes in claw shape at monthly intervals are shown in Table 3. Because of a floor effect on claw angle and an interaction between floor and time on heel depth, their increases over time are presented by floor type. Claw angle on concrete floors increased 4 to 4.5^0 within about four months of trimming, while claws in SY became 2^0 steeper within the same period. Toe length, claw height and heel depth increased on average with 0.6, 0.5, and 0.6 cm, respectively, while marginal changes in claw width and diagonal were observed.

Horn hardness at the toe, sole, and heel bulb was highest in SY, but no main effect of floor type was found (Table 2). Hardness at the toe, heel bulb, and wall was influenced by time ($P < 0.01$). The time-dependent course of horn hardness at each of these sites is illustrated in Figure 2.

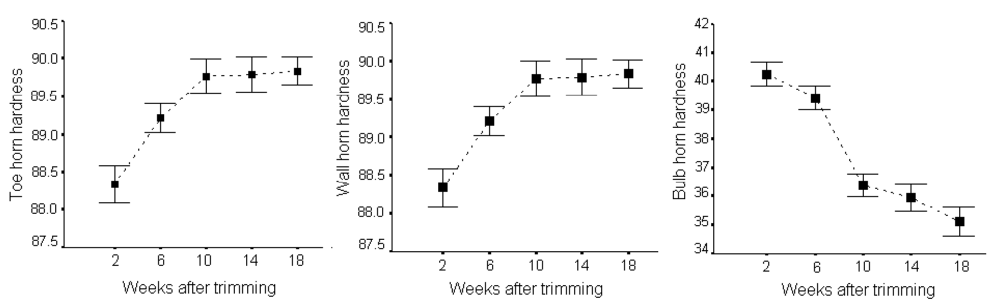

Figure 2. Changes in horn hardness at the toe, wall, and bulb with weeks after claw trimming. Values are presented as means ± S.E.M.

No main effects of floor type were significant for claw horn growth, wear, and net growth (Table 2). Rates of growth and net growth altered significantly through time and interactions between floor and time were found for growth, wear, and net growth. Least square means for horn growth and wear ranged between 4.2 and 6.6 mm/month and 2.6 and 3.0 mm/month, respectively (Table 4). This resulted in a net horn growth at any time, varying between 1.5 and 4.0 mm/month. Both growth and net horn growth were highest at the first measurement, when being 1.5 to 2.5 mm higher than at the following measurements. While all claws were trimmed prior to start of the study and cows were housed by that time, it is unclear which of those factors mainly induced accelerated horn growth. Therefore, we compared growth and wear before and after claw trimming while housed, as well as horn growth after claw trimming at the changeover between pasturing and housing and at the end of the housing season. Horn growth after claw trimming at the changeover between pasture and housing season was significantly higher ($P < 0.001$) than after trimming at the end of the housing season (Table 5). As the difference in horn growth before and after claw trimming was not substantial ($P = 0.484$), it seems clear that the increased horn growth is related to the turnover from pasture to housing. Trimming significantly reduced horn wear ($P = 0.025$).

Table 4. Temporal pattern of least square means for horn growth and wear rates.

	WEEKS AFTER TRIMMING					
	2 - 6	6 - 10	10 - 14	14 -18	18 - 22	22 - 26
Growth[1]	6.6[a]	5.0	5.0	5.1	4.2[b]	4.8
Wear	2.6	2.6	2.6	2.6	2.7	3.0[a]
Net growth[1]	4.0[a]	2.3	2.4	2.4	1.5[b]	1.8[b]

Values with different superscripts in the same row differ significantly ($P < 0.05$).

[1] mm/month

Table 5. Analysis of effect of housing and claw trimming on horn growth and wear in dairy cows. Data are presented as mean rates; bold figures give the significant difference at $P < 0.05$.

	AFTER TRIMMING		BEFORE TRIMMING			
	At changeover pasturing-housing	During housing	During housing	Difference between groups	N	Paired T-test
Growth[1]	6.9	5.0	-	1.9	78	**0.001**
Growth[1]	-	5.0	4.8	0.2	88	0.484
Wear[1]	-	2.5	2.9	-0.4	88	**0.025**

[1] mm/month

Claw lesions

IDHE. Statistical analysis of IDHE categories across five monthly intervals after trimming reveals an effect of time ($P < 0.01$). IDHE was neither significantly affected by floor type ($P = 0.39$) nor interaction between floor and time ($P = 0.40$). The development of IDHE through time is shown in Figure 3. Trimming occurred in week 0. At the first inspection two weeks later, IDHE lesions were mostly absent (57%) or mild (category 1; 37%). By six and ten weeks after trimming, the proportion of mild lesions was almost unchanged, whereas the proportion of claws with no signs of IDHE decreased drastically to 14 and 3%, respectively. About 5% of the claws had already moderate lesions (score 2) two weeks after trimming. From ten weeks, most IDHE lesions were of category 2 and higher. Severity of IDHE progresses steadily during the next months, resulting in approximately half of the lesions being diagnosed as serious or severe (category 3 and 4, respectively) from week 18 on. Least square means of IDHE lesion scores increased by 3.8 point between two and 18 weeks after trimming (Table 6).

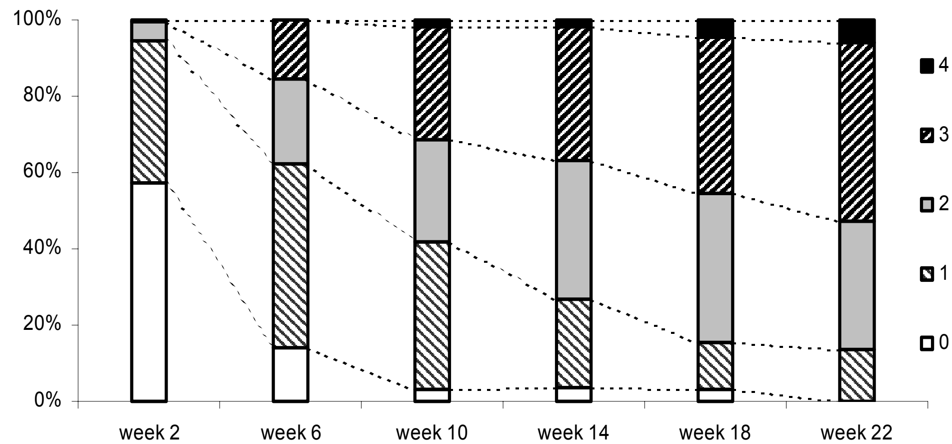

Figure 3. The distribution of the percentage of hind claws within each category of interdigital dermatitis/heel erosion (IDHE) during five months after claw trimming (week 0) observed in hind claws of 240 dairy cows. Severity and extent of IDHE was rated on a scale of 0 - 4 (0 = absent; 4 = severe).

Table 6. Least square means of lesion scores for interdigital dermatitis and heel erosion (IDHE) with time after claw trimming observed in hind claws of 240 dairy cows. Severity and extent of IDHE was rated on a scale of 0 – 4 (0 = absent; 4 = severe). Lesion score per cow was calculated as the sum of IDHE score in both hind feet.

Weeks after trimming	2	6	10	14	18
Mean lesion score	0.9	2.8	3.8	4.2	4.7

DD. Lesions of DD were affected by floor type (*P* = 0.07). Cows in SY had the lowest lesion scores for DD, while cows on SL had significantly less DD than cows on SC and GR. Although time was not statistically significant in the model (*P* = 0.18), there was a rather strong fluctuation in presence of DD lesions over time within each floor system. Mean lesion scores for DD had a range of 0.5 – 1.1 on SL, 1.1 – 1.6 on SC, 1.0 – 1.5 on GR, and 0.2 – 0.5 in SY (Figure 4). The variation through time is unstructured and seems neither related to the duration of housing, herd trimming events (at week 0 and from week 18 onwards), or therapy. Most farms applied footbaths with non-antibiotic solutions such as formaline and chemical disinfectants (e.g., copper sulphate) on a monthly or two-weekly basis; however, incidences of DD did not structurally decrease throughout the study.

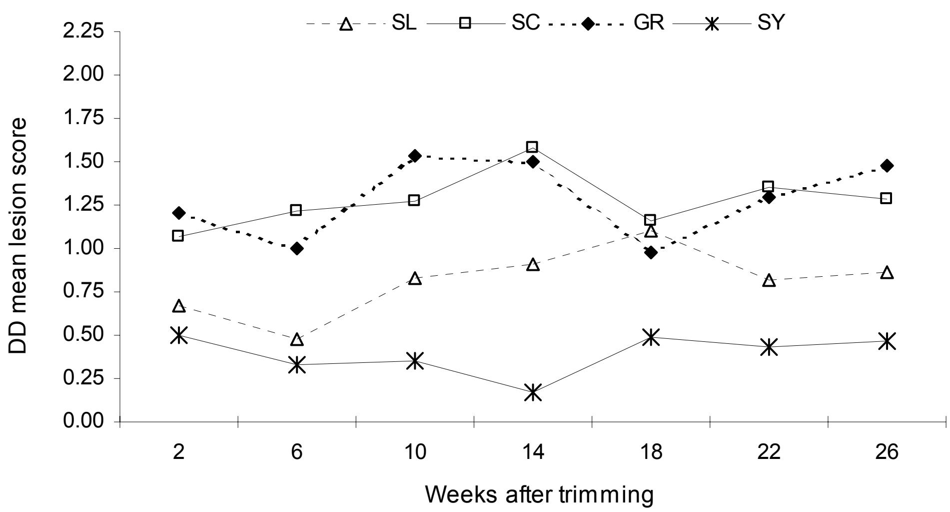

Figure 4. Mean lesion scores for digital dermatitis (DD) in a longitudinal study among 240 dairy cows kept on different floor types (SL = slatted floor; SC = solid concrete floor; GR = grooved floor; SY = straw yard). Active lesions of digital dermatitis were rated on a scale of 0 - 2 (0 = absent; 1 = moderate ulcerative lesion, < 1.5 cm in diameter; 2 = severe lesion, > 1.5 cm in diameter). Lesion score per cow was calculated as the sum of DD score in both hind feet.

The used scoring system for DD enables to follow the development of different disease stages. Figure 5a shows the distribution within categories M1 – M5 at five monthly observations. M1 and M2 lesions ranged between 10 - 20% and 15 – 20%, respectively. Healed lesions with skin abnormalities (M4) were observed in 5 to 15% of the hind claws, whereas 50 to 65% of the cases were negative (M5) with respect to DD. M3 lesions were barely observed due to their short existence after therapy. To give information on the prognosis with regard to DD, Figures 5b – 5d illustrate the over-time course of stages M1, M2, and M5, respectively. It can be seen that the majority of M2 and M5 lesions remain

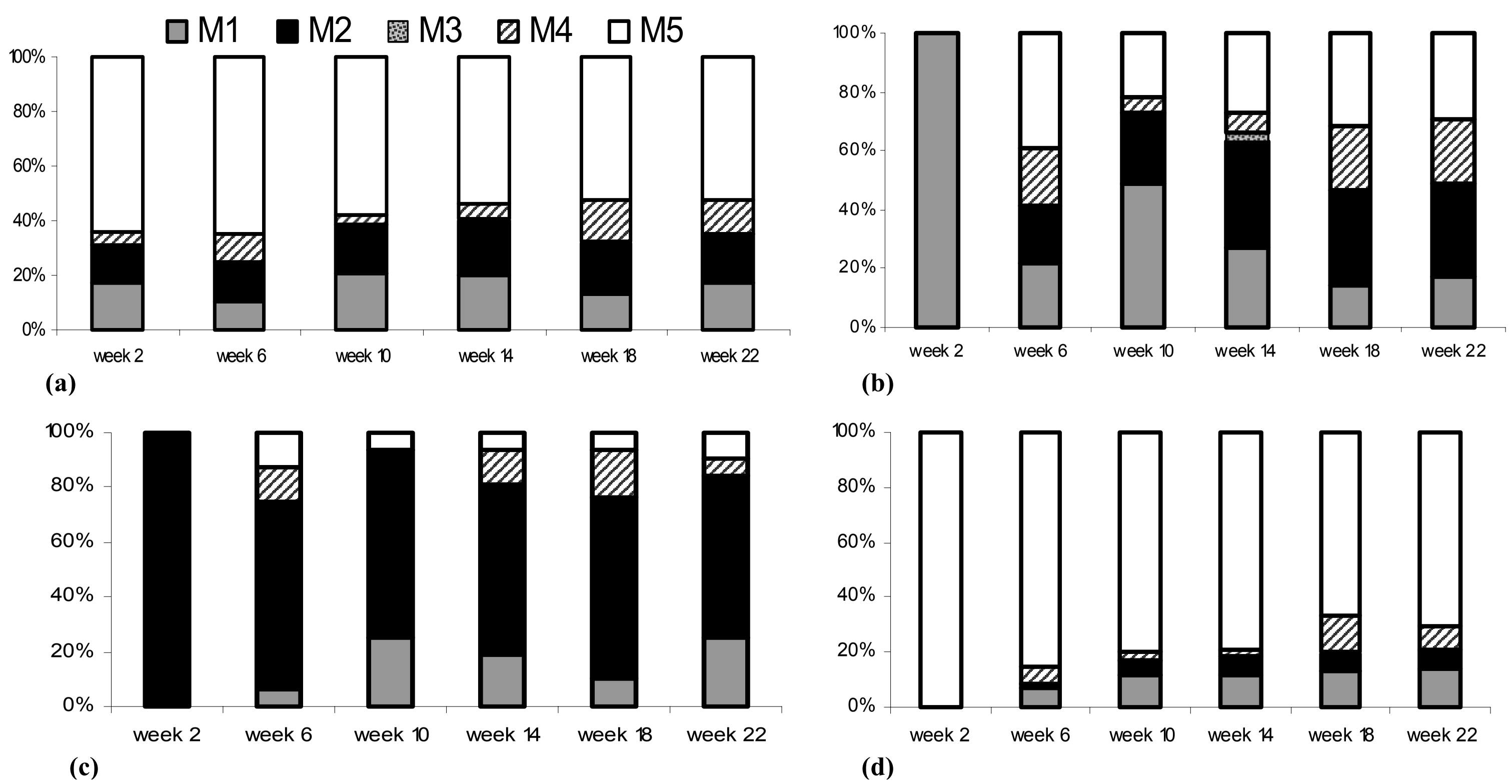

Figure 5. Changes in (a) digital dermatitis scores (M1 = early stage, granulomatous area, 0.5-2 cm in diameter; M2 = classical ulcer, 2 cm or more in diameter; M3 = healing process, lesion covered by scab; M4 = skin affected due to former M1 or M2 lesion; M5 = no visible lesion, skin unaffected; based on the definitions by Döpfer (1994)) and development within initial categories (b) M1 (n = 41), (c) M2 (n = 32), and (d) M5 (n = 151) with time after housing and week 2 as starting point.

invariable. Conversely, M1 lesions are rather unstable and often turn into other disease stages. In the present illustration of development of DD stages, the first observation after trimming (week 2) has been taken as starting point. When the second (week 6) or third observation (week 10) is set as starting point, a similar picture regarding M2 and M5 lesions comes forward. M1 lesions, however, are still variable but cure less quickly. One month after the chosen point of departure, respectively 70 and 68% of the M1 lesions remains an active lesion (either M1 or M2), whereas in the above situation this percentage was about 40%. At herd trimming, all claws were generally treated preventively with an antibiotic spray. This may be an explanation for the improvement of M1 lesions shortly after trimming.

DISCUSSION

It has been demonstrated that in addition to housing environment, both age and calving influence claw shape and development of lesions (Alban, 1995; Vaarst et al., 1998; Offer et al., 2000; Webster, 2001). As populations were about similar in all groups of floor types with regard to parity and stage of lactation, we assume both factors to be eliminated in the flooring comparison. Hind claws only were subjected to claw inspections since lesions are predominantly present in hind claws. For practicality, information on claw traits was obtained from right lateral hind claws only. Andersson and Lundström (1981) concluded that measurements of one hind claw are representative for estimating the size of hind claws. Although horn wear tended to be greater in lateral claws, Tranter and Morris (1992) found no difference in horn growth between the lateral and medial hind claw. Finally, Boelling and Pollott (1998) produced conclusive evidence that claw traits recorded on only one claw of one hind foot give a representative picture of both claws on both hind feet. Significant herd effects were found for all variables observed in the present study, but not presented as results. While farm selection within each floor type was aimed to include herds that were comparable with regard to housing, feeding, and management, the effect of farm factors other than floor type have all been kept included in the herd effect.

The present study investigated differences in horn growth and associated changes in claw shape in dairy cows kept on different types of flooring. It has been hypothesised that concrete floors may result in malformation of dairy claws due to disturbance in horn production and increased wear and tear (Murphy and Hannan, 1987; Vermunt and Greenough, 1995). However, we found no differences in horn growth and wear between cows on slatted (SL), flat concrete floors (SC, GR), and cows in straw-based systems (SY) during a full winter season. This agrees with Webster (2001), who found no effect of floor surface on horn growth and wear rates in heifers housed in cubicles and SY. Schlichting (1987), however, reported a decreased horn growth and wear in calves kept on deep litter compared to those on concrete flooring. It has been shown previously that claw lesions are less frequent and less severe in straw than in cubicle housing (Hughes et al., 1997; Livesey et al., 1998; Webster, 2001; Somers et al., 2003). Our study, however, does not show evidence that differences in infectious claw health between cows kept on concrete flooring and in straw are related to different horn growth and wear rates and subsequent claw shape.

Horn growth was highest by the time of changeover between pasturing and housing, probably induced by a change in foot environment from soft (grassland) to hard surfaces (concrete). It is believed that increased pressures exerted to the sole- and bulb-area leads to extra horn production (Murphy and Hannan, 1986). Also changes in feed composition at the start of housing may contribute, as it is known that horn growth is increased in cows fed high-protein rations (Manson and Leaver, 1988). A review on wear rates varying between 3 to 7 mm per month (Vermunt and Greenough, 1995) indicates that abrasion of claw horn is relatively low in our study. This may be caused by low frictional properties of the concrete passageways. Contrary to Manson and Leaver (1989), claw trimming had no stimulating effect on horn growth. However, our observation of decreased wear after claw trimming agrees with those authors.

Free-stall housing has been associated with both a decrease (Gilmore, 1978; Meyer and Galbraith, 1998) and increase in claw angle (Peterse, 1987). In the present study, claws on all floor types became steeper during housing, the increase occurred more rapidly on concrete floors than in SY. Claws may become steeper by either overgrowth of claw horn at the back of the claw (i.e. sole centre and bulb area; indicated as zone 4 and 6 by Greenough and Vermunt, 1991), or increased horn wear underneath the toe area. While increase in claw height and heel depth was comparable between cows on concrete and straw (Table 4), it is reasonable that claws in straw yards show less horn abrasion at the toe. Overall, claw angle was significantly smaller in cows in SY. This has also been observed by Meyer and Galbraith (1998). For functional weight bearing, the ideal claw angle has been suggested at 50 to 55^0 (Fessl, 1982). Based on normal claw shape, one could notice that weight bearing is better regulated on concrete floors. However, elasticity of concrete is nil and the hard surface exerts high contact forces to the lateral hind claw with maximum-pressure concentrations located at the sole-bulb-area (Van der Tol, 2004). The biomechanical problem of abnormal load bearing is strongly reduced in SY because cows are less exposed to mechanical stress while standing and walking in the deep litter area. Providing soft walking areas, e.g. rubber or straw, in general will enable a more natural weight bearing within bovine claws, and this may lead to better claw health as overloading has been mentioned as a main factor in the occurrence of claw diseases (Toussaint-Raven, 1973; Bergsten and Frank, 1996; Van der Tol et al., 2003). Another way to improve functional load bearing is claw trimming. One of the goals of the Dutch trimming method is to reduce weight bearing underneath the prone part of the claw, i.e. the bulb area and sole centre (Toussaint-Raven et al., 1985). This can be achieved by increasing the claw angle, which leads to a forward shift in weight bearing towards the toe. Conversely, although not presented as results, we found that lateral hind claws became shallower after trimming (on average 4 to 5^0), suggesting that weight bearing in hind legs is still not optimal after preventive trimming.

Claw traits other than claw angle did not significantly differ between floor types, which is in line with previous research, where no differences in claw dimensions were found between cows in straw-based and cubicle housing (Fregonesi and Leaver, 2000). We expected to detect differences in horn hardness due to floor surface, as dirt and moisture have been associated with decreased horn hardness (Baggott et al., 1988). Cows in SY are generally less exposed to moisture on the floor compared to cows in cubicle houses. No differences in horn hardness, however, were found between cows in SY and on concrete floors, following Webster (2001). Conversely, in a German study it was demonstrated that claws of cows on SL were harder than on SC, while horn hardness was highest on slats covered with rubber mats (Meyer, 2002).

Lesions of IDHE developed gradually over time, and disease manifestation in this study was unaffected by floor type. This contrasts with the cross-sectional survey by Somers et al. (2003) showing that IDHE was less severe in SY than in cubicle houses with concrete floors. An explanation for the contrasting results may be the study population. The floor comparison in the cross-sectional was based on a large sample of dairy herds whereas in the present longitudinal study only three herds per floor system were studied. Additionally, SY cows in the current study were well comparable to the modern Dutch dairy cow with regard to milk yield and breed, whereas in the previous study SY herds were characterised by a less-intensive management. They also had (partly) other breeds than the common Holstein-Friesian (e.g. Mont-Beliardes, Jersey).

It speaks up for the design of the longitudinal study that claws of all cows were trimmed prior to the study. This justifies the assumption that claws exposed to different floors were comparable at the onset of the study with regard to IDHE status. Similar interval after trimming has been stated as an important condition for comparing claw health in a study population (Enevoldsen and Gröhn, 1991). In this respect, it is noteworthy that severe lesions of IDHE do not completely disappear after claw trimming. Deep grooves are cut out but it takes quite some time before the loss of heel horn is fully covered. This may be the reason that 5% of the claws in the present study had already moderate IDHE lesions two weeks after trimming. Yet, trimming is highly advisable to restore claws from heel horn damage (Toussaint-Raven et al., 1985).

DD has generally been recognised as a widely occurring infectious and painful disease, often associated with lameness. Much work has been performed to clarify the aetiology and provide evidence on risk factors involved (reviewed by Berry et al., 2004). The course of DD shortly after antibiotic treatment has also been monitored (Mumba et al., 1999; Shearer and Hernandez, 2000). The present study is the first to investigate the course of DD over a longer period and the development of each of the disease stages in particular. The rate of healing in M2 lesions was about 20%, while 30 to 60% of the M1 lesions developed into healed stages. These figures contrast sharply with the healing rate post antibiotic therapy calculated at 90% by Brizzi et al. (1993). After reviewing several treatment studies on DD, Shearer and Hernandez (2000) concluded that efficacy of individual treatment varies enormously, regardless of the method. Together with a considerable infection rate, assessed at 20% in unaffected claws over a five-month period, and recurrence of M1 and M2 lesions, our results confirm that DD is a chronic infectious disease that occurs frequently in modern dairy housing. The disease can hardly be controlled without reapplied antibiotic topical treatment (Bergsten, 1997), given that most herds applied non-antibiotic footbaths during this study without important efficacy. In particular cows at stage M2 do have a poor prognosis recovering from DD. Green and Döpfer (2004) account a finely tuned host-agent equilibrium for the fact that classical ulceration or M2 lesions persist for a long time. A farmer should therefore make extra efforts to treat these problem animals adequately. Not only to preserve them from pain and discomfort but also to prevent healthy animals to become infected. Ruling out the majority of M2 cases at a time seems a good remedy for problem herds, all the more because it is quite conceivable that the situation will be structurally improved afterwards.

CONCLUSIONS

No structural differences in claw shape were found between cows kept on several concrete floors and in straw yards, except for claw angle. Horn growth and wear was also unaffected by floor type. Therefore, we have no indication that differences in claw health between concrete and soft flooring are related to horn growth and wear and associated claw shape. Lesions of IDHE increased gradually over time regardless of floor type. Claw trimming is a good cure for the heel horn damage. Cows in straw yard systems were the least infected by DD. Apart from this, the incidence of DD fluctuated irregularly in time. Classical lesions of DD are generally long-lasting and rather insensitive to claw trimming and frequent use of footbaths.

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Chapter 6

The Effect of Digital Lesions and Floor Type on Locomotion Score in Dairy Cows

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Submitted

ABSTRACT

The present study investigated the effects of digital lesions, as presented by digital dermatitis (DD) and interdigital dermatitis and heel erosion (IDHE), on locomotor performance in 240 dairy cows. Animals were from 12 commercial dairy herds, of which nine herds were kept in cubicle houses with concrete walking passageways (either slatted, solid concrete, or grooved) and three herds in straw yards (always with slatted floor in front of the feed bunk). Animals were monthly investigated for lesion severity of DD and IDHE and for locomotion score throughout the 1-yr study. Locomotor performance was rated by the locomotion score (ranging from 1 to 5, from normal to worse). The data including 1801 examinations were analysed in a split-plot design.

Severeness of DD lesions was strongly related to deterioration in locomotor performance. Lameness (locomotion score ≥ 3) increased from 14% in DD-negative cows to 35 and 38% in moderately and severely affected animals, respectively. At the same time, the proportion of normal locomotion (score ≤ 2) reduced from 64% to 39 and 31% for both groups of affected animals, respectively. DD and floor type interacted in their effect on locomotion score. Among DD-negative and slightly affected cows, animals kept in straw yards walked significantly better than those on slatted floors, while those on grooved floors walked significantly worse. Severe lesions of IDHE resulted in a higher mean locomotion score indicating a worse locomotion. Locomotor performance highly differed between the cubicle-house and straw-yard group. Over 81% of all gaits in straw-yard cows were scored as normal and less than 1% as clinically lame, while in cubicle-housed cows these percentages were 46 and 27, respectively. Recovery of lameness in the investigated animals was poor as disturbance in gait often endured for several months.

Abbreviation key: **DD** = digital dermatitis, **IDHE** = interdigital dermatitis and heel erosion.

INTRODUCTION

Good locomotion is an important issue in dairy loose-housing as it supports the main behavioural activities. To supply their different needs, cows in cubicle houses have to walk about 1 km daily or more (Kempkens and Boxberger, 1987; Schofield et al., 1991). The welfare implications of impaired locomotion are considerable (Whay et al., 1998) and twofold. First, pain and discomfort as experienced by lame cows can be severe. Second, and less recognised is the frustration as a result of suppression of behavioural activities due to reduced mobility (Metz and Bracke, 2003). Besides its welfare implications, lameness has a significant economic impact given that it has been rated as the third health-related loss in dairy farming next to fertility problems and mastitis (Enting et al., 1997).

Many studies have been conducted to quantify the incidence of clinical lameness. Estimates of mean annual farm incidence of lameness over the last 10 years range from 7

(Alban, 1995), 22 (Whay et al., 2002), 38 (Kossaibati and Esslemont, 2000), 55 (Clarkson et al., 1996), up to 69 percent (Hedges et al., 2001). The great variability in reported lameness incidences is likely to result from an increase of lameness at dairy farms, and different measures and sources of lameness data. In the knowledge that lameness is of multifactorial origin, substantial research has been done to identify and quantify risk factors involved in it (e.g. Gröhn et al., 1992; Alban, 1995; Hughes et al., 1997). About 90% of all lameness cases originate from claw disorders. As a consequence, presence and severity of claw disorders and its causal conditions have been surveyed (e.g. Enevoldsen et al., 1991; Bergsten, 1995; Somers et al, 2003). Nevertheless, observational studies into the relationship of locomotor problems and claw disorders as such are scarce (Green, 2003). Manske et al. (2002) related claw lesions and lameness occurrence and showed that of cows with claw disorders (72%) only a small percentage was diagnosed clinically lame (5%). A similar study of Frankena et al. (1991) showed that less than 1% of cows with affected claws were lame. Both studies, however, had a cross-sectional design. The main goal was prevalence estimation at large scale and not a critical gait analysis.

Locomotion scoring is a proper method of measuring the degree of gait disturbance in cows. In addition to cases of clinical lameness, also cows with an 'abnormal' locomotion pattern (e.g. uneven gait, ab/adduction of limbs, stiffness) can be encountered in this method (Green et al., 2002). For a better understanding of the role of claw disorders in the development of disturbed locomotion – with its negative impact on cow activity and welfare –, a detailed monitoring of both phenomena over a certain time period is essential. Ideally, the physical environment in which a cow is kept should also be considered. Housing type (e.g. cubicle vs. straw yard) and floor properties (e.g. slatted vs. solid, wetness, softness) not only influence prevalence of claw disorders and lameness, but also easiness of movement (Phillips and Morris, 2000; Benz et al., 2002; Somers et al., 2003).

The aim of the present study was to investigate the effects of type and severity of claw lesions on cows' locomotion. Claw health and associated locomotor performance were examined throughout a 1-yr period in dairy cows kept on several floor systems.

MATERIALS AND METHODS

Study population

The data for this study were from 240 Holstein-Friesian animals from 12 commercial dairy herds across The Netherlands. Detailed information on the selection procedure of study herds and animals and their characteristics is given in Chapter 5. In short, each herd supplied 20 dairy cows. Equal numbers were randomly selected from parity classes 1, 2, 3, and ≥ 4. Herds were kept on one of the following floor systems: slatted floor, solid concrete floor, grooved floor and straw yard (n = 3 for each floor type). The 305-DIM yield of study animals on slatted, solid concrete, and grooved floors, and in straw yards averaged 8700, 8300, 9000, and 8000 kg, respectively.

Data collection

Hind claws of all animals were monthly examined for digital lesions of interdigital dermatitis and heel erosion (**IDHE**) and digital dermatitis (**DD**). Lesions were scored for severity as described in Chapter 5: score 0 to 4 for IDHE and 0 to 2 for DD. Other digital lesions (i.e. interdigital hyperplasia and interdigital phlegmon) and lesions of the claw horn such as sole ulceration and white line disease were also recorded if visible without any horn trimming. Animals' locomotion was scored after each claw inspection according to the system by Manson and Leaver (1988). The nine possible scores (scale of 1 to 5 with half-points in between) cover the broad range between perfect gait (score 1) and extreme lameness (score 5), and therefore it pre-eminently fits for monitoring of individual changes in locomotion. Instead of on-site scoring, locomotion of each animal was videotaped with a digital video camera. The first author assessed all the video recordings afterwards.

The observation period was between April 2002 and May 2003. All herds were at pasture during the summer period and no data were recorded then. Prior to that summer, all animals were examined three times. At the start of housing, claws of all cows were trimmed (September/October). Data recording resumed two weeks later. From that time on, depending on timing of pasturing and trimming, herds were examined another six to eight times. In total, 1801 paired recordings of claw lesions and locomotion scores obtained from 215 animals were available for analysis. Those animals were examined at five to eleven monthly intervals during the study (Table 1). Data from 25 animals were excluded due to a limited number of observations per cow (< 5). Lacking data were mostly due to cows that had not been examined when being dried off or animals that had been culled. Individual data recorded prior to culling were retained in the dataset if the number of examinations so far was five or higher. One of the herds with a slatted floor was pre-emptive slaughtered after the third round of farm visits because one cow was diagnosed with BSE. In the summer period, this farm was replaced by another farm with the same floor type and which came from the same pool where the initial 12 herds had been selected from (and thus, the same inclusion criteria were fulfilled). Similarly, 20 animals were selected and examined at most eight times.

Table 1. Frequencies of observations per cow among 215 animals that were examined at five to eleven monthly intervals between April 2002 and May 2003.

Examinations/cow	11	10	9	8	7	6	5
Number of cows	19	41	44	53	24	24	10

Data analysis

Monthly locomotion scores were analysed by a split-plot repeated measures ANOVA (PROC GLM of SAS, 1996) with the model including cow lesion scores for IDHE and DD, and variables flooring and time; interactions between IDHE and DD, IDHE and flooring, and DD and flooring were tested as well. The statistical model containing all variables revealed that the interaction terms of IDHE with variables DD and flooring were non-significant ($P > 0.10$) and subsequently removed. The final model was as follows:

$Locomotion_{ijklm} = \alpha + IDHE_i + DD_j + Floor_k + (DD\ x\ Floor)_{jk} + Time_l + Herd_m + \varepsilon_{ijklm}$,

where

$Locomotion_{ijklm}$ is the locomotion score at cow level,

α is the overall mean,

$IDHE_i$ is the IDHE cow score (i = 1, 2, 3); initial cow scores for IDHE (with maximum score is 8, i.e. lesion score 4 in both hind legs) were categorised into three classes to reduce possible outcomes as follows: 1 = slight (cow score 0 to 2; no distinct class 'IDHE-negative' was included because of limited numbers), 2 = moderate (cow score 3 and 4), 3 = severe (cow score 5 to 8),

DD_j is the DD cow score (j = 0, 1, 2, 3; with 0 = negative (score 0 in both legs), 1 = slight (score 1 in one or both legs), 2 = moderate (score 2 in one leg, 0 in the other), and 3 = severe (score 2 in one leg and score 1 or 2 in the other)),

$Floor_k$ is the floor type (k = 1, 2, 3, 4; with 1 = slatted concrete, 2 = solid concrete, 3 = grooved concrete, and 4 = straw yard),

$Time_l$ is the sequence number of observation (l = 1, 2, 3, ... 11),

and ε_{ijklm} is the residual.

In addition, a follow-up model was analysed dealing with the comparison of straw-yard versus cubicle housing. The variable $Floor_k$ with k = 1 to 4 was replaced by the variable $Housing_k$ (k = 1, 2 with 1 = cubicle house, 2 = straw yard). Both interaction terms containing DD were not significant and removed from the final housing model: $Locomotion_{ijklm} = \alpha + IDHE_i + DD_j + Housing_k + (IDHE\ x\ Housing)_{ik} + Time_l + Herd_m + \varepsilon_{ijklm}$. The main effects in both models, being *Floor* and *Housing*, respectively, were tested using the mean square of herd either nested within floor and housing system, respectively, as the error term. All other effects were tested against the residual mean square. The Shapiro-Wilk's test of normality ensured that residuals were normally distributed. In case of significant effects or interactions, multiple comparison tests were performed using the Bonferroni correction. Data on locomotion score are presented as means ± SEM. At some points, for interpretation terms, locomotion is expressed in qualitative terms: normal, tender, and disturbed locomotion. The locomotion scores were then categorised into three classes as follows: normal = locomotion score 1 to 2, tender = score 2.5, and disturbed/lame = score 3 to 5.

RESULTS

Locomotion

Floor model. There were significant effects of DD ($P < 0.001$) and IDHE ($P < 0.001$) on locomotion score, and also the interaction between DD and floor type was significant ($P = 0.01$). Cows without DD showed significantly lower score for locomotion (i.e. better locomotion) than those that were moderately and severely affected, while they tended to show better locomotion than animals with slight symptoms of DD (Table 2). The interaction between DD and floor system was significant ($P = 0.01$) and is illustrated in Figure 1. Among DD-negative cows, animals kept in straw yards walked significantly better ($P < 0.001$) than those on slatted floors (reference floor type), while those on grooved floors walked significantly worse ($P < 0.001$). Regarding slightly affected cows, the same yields with significance at the 10% level ($P = 0.09$ and $P = 0.09$, respectively). Locomotion in cows showing moderate and severe lesions of DD was unaffected by floor type. Regarding IDHE, severe lesions resulted in a significantly higher score for locomotion (i.e. worse locomotion), while moderate lesions tended to increase locomotion score compared to the reference score in the pooled negative/slight-group (Table 2).

The main effect of floor type was not significantly related to the locomotion score ($P = 0.39$), as was the effect of time ($P = 0.13$).

Table 2. The effect of lesion severity of digital dermatitis (DD) and interdigital dermatitis/heel erosion (IDHE) on locomotion score (means ± SEM) according to the floor model.

Lesion severity	DD	N[1]	*P*-value	IDHE	N[1]	*P*-value
Negative	2.23 ± 0.02	962	[2]	[3]	-	
Slight	2.45 ± 0.03	354	0.08	2.29 ± 0.02	697	[2]
Moderate	2.59 ± 0.05	177	< 0.001	2.37 ± 0.03	530	0.08
Severe	2.62 ± 0.04	249	< 0.001	2.47 ± 0.03	515	< 0.001

[1] Number of observations

[2] Set as reference score

[3] No distinct class of 'Negative' was included because of limited numbers of IDHE-negative records; scores of IDHE-negative cows were pooled with those of slightly affected ones.

Housing model. The housing model revealed significant effects of housing ($P = 0.03$) and DD ($P < 0.001$) on locomotion score. Mean locomotion score was significantly lower in the straw-yard group (1.98 vs. 2.46 for cubicle-housed cows), indicating better locomotion. The percentage of locomotion assessed as normal, tender, and disturbed highly differed between both groups (Table 3). Over 81% of the gaits observed in straw-yard cows were recorded as normal, about 18% as tender, and less than 1% as clinically lame. Among cubicle-housed cows these percentages were 46, 27, and 27, respectively. With increasing severity of DD, the proportion of normal locomotion declined from 64% in DD-negative cows to 47, 39, and 31%, in slightly, moderately, and severely affected animals, respectively. At the same time, lameness increased from 14% to 25, 35 and 38%, respectively.

The effects of time ($P = 0.31$) and IDHE ($P = 0.09$), and the interaction between IDHE and housing ($P = 0.07$) were not significant in the housing model.

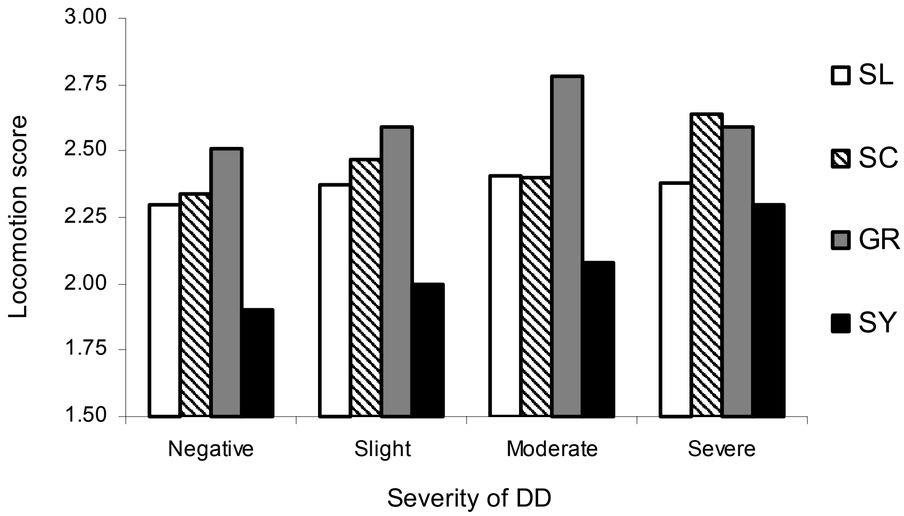

Figure 1. Interaction of digital dermatitis (DD) and type of floor (SL = slatted, SC = solid concrete, GR = grooved, SY = straw yard) on locomotion performance (as presented by locomotion score according to Manson and Leaver, 1988). Bars within DD category with different letters above differ significantly at $P < 0.05$; those with different capital letters above differ significantly at $P < 0.10$

Table 3. Differences in locomotion between cows kept in cubicle houses with concrete passageways and cows in straw yards.

Definition	NORMAL			TENDER	LAME				
Locomotion score	1	1.5	2	2.5	3	3.5	4	4.5	5
Cubicle housing	0	5.5	40.9	26.6	15.8	6.8	3.7	0.6	0.1
Straw yard	1.1	21.8	58.5	17.6	0.3	0.6	0	0	0

Lameness

The distribution of lameness occasions per cow during the study period is given in Figure 2. Over half of the cows (= 116/215) were never recorded as lame. Fifty-six cows were lame at three or fewer examinations. Thirty-one cows were scored as lame on six or more occasions, of which eleven cows (5% of the population) were lame all the time. Observing an animal as lame at the fourth observation (t = 4; i.e. first examination after trimming at the start of housing in September/October 2002), she also was likely lame at coming monthly examinations (Figure 3). Conversely, cows with normal locomotion have good prognoses for staying 'healthy'. For example, less than 10% of cows that walked normal at t = 4 became lame during three following inspections. In about 40% of the cows that walked tender at t = 4, walking performance remained unchanged over a period of three months.

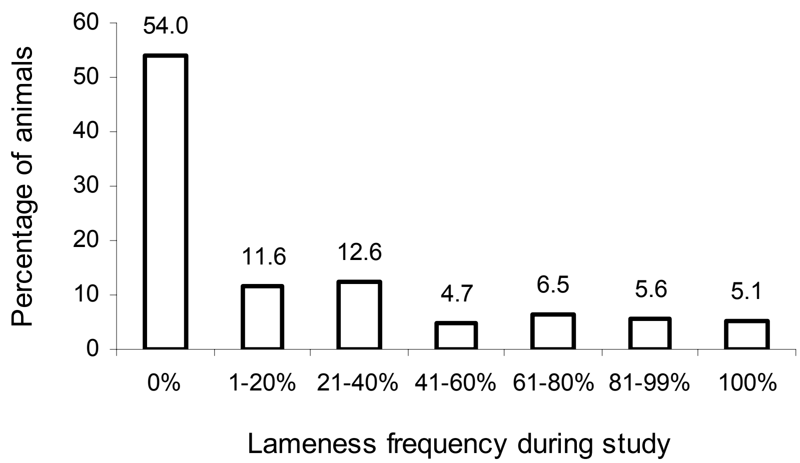

Figure 2. Distribution of individual lameness occasions (in %) among 215 cows calculated out of five to eleven monthly examinations between April 2002 and May 2003; '0%' indicates that a cow never had a locomotion score 3 and above, and '100%' indicates that a cow was diagnosed lame at all the examinations.

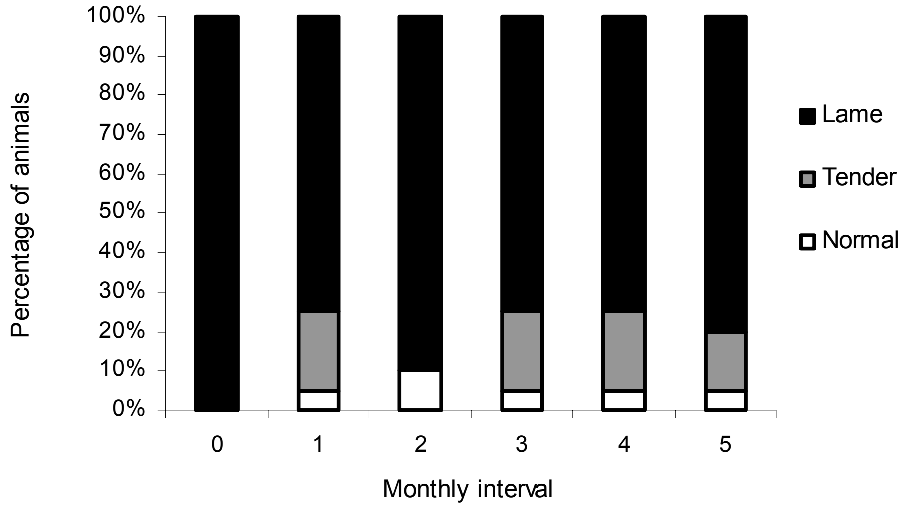

Figure 3. Five-monthly development in locomotor performance examined in 35 cows that were diagnosed lame at the fourth observation within the longitudinal study (set as reference observation and consistent with monthly interval 0); 'normal' indicates locomotion score ≤ 2, 'tender' = score 2.5, and 'lame' indicates score ≥ 3.

DISCUSSION

Lameness may be seen as the most reliable indicator of pain and discomfort suffered from afflictions at the bovine limb (Potter and Broom, 1990). Locomotion, and thus lameness, was evaluated in present study according to the Manson and Leaver locomotion score (1988). The scoring system comprises an extensive range of scores, and is therefore well-suited for monitoring changes in walking quality due to claw lesions.

A large variety of claw lesions are implicated in lameness (Murray et al., 1996). To date, there is conflicting information on the common cause of lameness. Clarkson et al. (1996) stated that lesions of the claw horn (e.g. sole ulceration, white line disease) were the most responsible for lameness, while another UK study demonstrated that skin lesions (e.g. DD, interdigital phlegmon) were the major source (Offer et al., 2000). The present study clearly indicates that infectious skin lesions (referred to as digital lesions) and DD in particular, deteriorate walking quality in dairy cattle. Besides impairing normal locomotion, DD often resulted into clinical lameness. Previous studies have also reported a discrete relationship between DD and lameness (Murray et al., 1996; Winckler and Willen, 1999; Offer et al., 2001). Although no clear association has been demonstrated between IDHE and lameness (Logue et al., 1994; Livesey et al., 1998), our results indicated a significant increase in locomotion score with progressing severeness of IDHE. Loss of stability and cushion capacity due to irregular heel erosion might be the underlying mechanism of deterioration in locomotion.

In this study, lameness appeared to be a persistent event (Figure 2 and 3). This result is consistent with Clarkson et al. (1996), who reported an average duration of 140 days per lameness case. One explanation might be that farmers are unable to detect all the actual lameness cases within their herd (compared to a trained observer) (Wells et al., 1993; Whay et al., 2002). Farmers are sensitive to obvious lame cows (locomotion score 3.5 and above), but cases of slight to moderate lameness are less well recognised. In the present study, mildly lame constituted the majority of the lame cow population. Without identification, no treatment follows and disturbance in locomotion may endure for a long period of time. An alternative explanation is that cows have difficulties to recover from DD (Green and Döpfer, 2004) and DD was identified as an important cause of lameness in the present study and confirmed by others (Offer et al., 2000; 2001). The poor recovery from DD was also demonstrated in Chapter 5. Classical ulcers of DD proved to be rather insensitive to claw trimming and frequent use of footbath, and as a consequence lesions were usually long-lasting.

Cows kept in straw yards walked significantly better than cubicle-housed cows. This result agrees with work by Hughes et al. (1997) evidencing that lameness is dramatically reduced in straw yards. Not only was the level of lameness considerably lower in straw-bedded systems in our study but also the majority of locomotion was scored as normal (even gait without tenderness of feet or asymmetry). At one hand this can be attributed to a better claw health (i.e. lower incidences of DD), at the other hand marked differences in housing and flooring design play an important role. The benefits of straw-yard systems are dual. First, lower mechanical stresses are applied to the claw and consequently to the skin surrounding the claw whilst walking and standing on straw bedding (as a soft surface enables a more natural load bearing) (Scott, 1988). Secondly, the straw-bedded area provides a more comfortable lying environment than most cubicles, resulting in longer lying times (Singh et al., 1993). As a matter of fact, straw-yard cows are spending much less time on concrete passageways, and thus having lower risk for developing claw lesions and subsequent lameness (Livesey et al., 1998). A secondary benefit of increased lying down is recovery from claw disorders.

Trimming restores normal claw shape and intends to improve load bearing within the claw (Toussaint-Raven et al., 1985). It was then expected that walking quality would have substantially improved in cows with freshly trimmed claws. However, the frequency of lameness two weeks after claw trimming was surprisingly high among cows in cubicle houses: on average 22% (not presented as results). The poor walking performance may be partly addressed to locomotion-impairing lesions that did not cure after trimming, in particular DD. The presence of lesions other than DD and IDHE was also scored in this study. However, occurrence of those lesions was low at all our observations (less than 4% of whom the majority concerned interdigital hyperplasia) and hence, considered of minor importance in the analysis. The mechanical component involved the claw-floor interaction might be responsible for the unexpected result as well. Recent biomechanical work evidenced that abnormal high pressures are applied to lateral hind claws while cows are walking on concrete surfaces (Van der Tol et al., 2003), and therefore overloading has been postulated an important factor in pathological processes resulting in lameness (Van der Tol, 2004). Backed up by the knowledge that loading is considerably reduced on soft surfaces, reported benefits of straw-bedded areas and rubber-covered floors for unrestricted locomotion are rational (Rowlands et al., 1983; Benz et al., 2002). Finally, locomotion might be adversely affected by poor design of resting places and hence, less optimal lying comfort. In a British survey, it was concluded that lameness and worse locomotion were strongly related to poor cubicle design due to poor bedding and incorrect cubicle dimensions, kerb-height, and placement of head-rail (Faull et al., 1996).

A substantial proportion of the cows showed a certain degree of abnormality and unevenness at walk, i.e. ‘tender’ locomotion. Those animals will be at increased risk for developing lameness; their stiff gait and tender feet may be indicators of pain, and the ab/adduction in hind limbs an attempt to relieve pain. Adjustments in gait and posture together with a cow’s natural instinct to mask suffering of pain and discomfort (O’Callaghan, 2002) enable her to challenge adverse claw - floor interactions. Consequently she shows no clinical signs of lameness. However, the animal is undeniably affected and more than likely she feels pain. It is important that, in case the state of discomfort persists or severeness of lesions progresses, farmers give extra attention to such animals and prevent them from lameness.

CONCLUSIONS

This study has shown that infectious skin conditions of the claw highly affect locomotion in dairy cattle. Not only severe stages of DD and IDHE but also milder forms caused significant disturbances in cow locomotion. This implies that animals with slight and moderate symptoms of these digital lesions might suffer from pain and discomfort and subsequent compromised welfare. Manifestation of gait disturbance was strongly reduced in straw yards compared to cubicles houses with concrete passageways. The vast majority of straw-yard cows had no abnormality in walking, while half of the cubicle-housed cows showed either tender or disturbed locomotion. Recovery from lameness was poor as disturbance in gait often endured for certain months.

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Chapter 7

The Effect of Digital Dermatitis and Locomotion Score on Daily Behavioural Activity in Dairy Cows

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Submitted

ABSTRACT

The aim of the present study was to examine the effect of locomotion score and digital dermatitis on cow behavioural activities in three cubicle-housed herds. In addition, time budgets were compared between groups of non-lame cows in a straw yard, and lame and non-lame cows in cubicle houses. The behavioural state of 18 cows per cubicle-herd was recorded every 15 min during 2 x 24-hr periods at 14 days after claw trimming and repeated at 3.5, 4.5 and 5.5 months after trimming. Behavioural activities scored were: 1) lying in cubicle, 2) standing in/half-in cubicle, 3) standing/walking in concrete passageway, 4) feeding and drinking, and 5) milking. Prior to each video observation, hind claws of the study cows were examined for digital dermatitis (DD) on a 0 – 2 scale, and locomotion of the animals was assessed on a 4-point scale (1 = normal; 2 = tenderness; 3 = slight lameness; 4 = severe lameness).

Lameness (indicated by higher locomotion score) and digital dermatitis caused significant disturbances of normal behavioural patterns. Slightly and severely lame cows had longer lying bouts than cows with normal and tender locomotion, but showed fewer bouts per day. Severely lame cows had shorter daily feeding time due to fewer feeding bouts. Cows with severe DD showed reduced lying time, and stood longer in cubicles than other cows.

Non-lame cows in the straw yard lay down for significantly longer and spent less time on concrete than lame and non-lame cows in the cubicle houses. Among cubicle-housed cows, lame animals spent more time standing in cubicles and tended to wait longer before entering the milking parlour.

Abbreviation key: DD = digital dermatitis, **LC** = lame cows in cubicle house, **NLC** = non-lame cows in cubicle house, **NLS** = non-lame cows in straw yard.

INTRODUCTION

One of the most important health problems of dairy cattle are claw and locomotor disorders. High levels of lameness are reported in dairy herds, mainly attributed to claw lesions (Alban, 1995; Hedges et al., 2001; Manske et al., 2002). In the last decades, a shift is seen from an economic-related problem (Whitaker et al., 1983, Barkema et al., 1994) towards concern about animal welfare (Webster, 1995; FAWC, 1998). Welfare can be described in terms of ability of animals to cope with their physical and social environment (Broom, 1996). The ability of cows to live in harmony with the environment and their herd mates is to a large extent determined by the health state of the claws and the functioning of the locomotor apparatus. Painless and unrestricted mobility is essential for cows to satisfy their biological and social needs (Metz and Bracke, 2003).

The physical reaction of cows to being lame or having a claw disorder is measurable in terms of their behavioural response. Normal behaviour is usually altered for a reason, for example having pain while walking. Adaptations in behaviour induced by lameness are shorter total lying and feeding times, and prolonged standing in cubicles (Singh et al., 1993; Galindo and Broom, 2002). In about 90% of cattle-lameness cases, claw lesions are the primary source. Conversely, claw lesions do not necessarily cause a visual disturbance in locomotion, either because no pain or discomfort is involved or due to animals' innate ability to mask suffering of pain and discomfort by behavioural adaptation (O'Callaghan, 2002).

In The Netherlands, infectious claw disorders are highly prevalent and a leading source of lameness in dairy cows. Particularly, digital dermatitis (**DD**) is an important disorder because of animal welfare concern and economic loss (Winckler and Willen, 1999; Hernandez et al., 2002). DD is a superficial, contagious claw disorder that causes ulcerative and proliferate lesions, usually at the skin area above the heels or near the interdigital space (Read and Walker, 1998). Currently, approximately 30% of the Dutch dairy cows kept in cubicle houses with concrete passageways have lesions of DD (Somers et al., 2003). High prevalences were also reported in other countries (Murray et al., 1996; Rodriguez-Lainz et al., 1996; Wells et al., 1999). Affected cows often suffer from pain and discomfort. Hence, the condition seriously impairs locomotor behaviour (Winckler and Willen, 1999; Offer et al., 2001). To our knowledge, no studies are available that investigate changes in behavioural activity due to DD.

The housing environment is an important factor in the aetiology of cattle-lameness. Poor claw health and disturbed locomotion have frequently been related with unfavourable floor conditions (e.g. unhygienic, wet, slippery, and hard concrete floors) and poor lying facility (e.g. incorrect cubicle dimensions, insufficient bedding) in dairy herds (reviewed by Bergsten, 2004). Given that straw-yard systems comprise both the benefit of soft walking surface and comfortable lying facility, it seems logical that cows in straw yards show less claw disorders and less lameness than cows kept in cubicle houses with concrete passageways (Hughes et al., 1997; Livesey et al., 1998; Somers et al., 2003; see also Chapter 6). Differences in cow behaviour between both housing systems may contribute to this fact.

The present study aims to assess the effect of locomotion score and DD on cow behaviour in terms of 24-hr time budgets. Furthermore, differences in daily behavioural activity between non-lame cows kept in a straw yard, and lame and non-lame cows in cubicle houses were investigated.

MATERIALS AND METHODS

Study population

This study is part of a 1-yr longitudinal research to examine relationships between claw disorders, disturbed locomotion, and behavioural activity in dairy cows kept on various floor systems (see Chapter 5). The present study was conducted in four herds that participated in the longitudinal study; three of them were housed in cubicle houses with concrete passageways (either slatted, solid, or grooved concrete) and the remaining herd in a straw yard. Data on housing and floor type, milk production, and number of cows of the farms are given in Table 1. At the start of the longitudinal study (April 2002), 20 cows per herd were selected randomly but stratified by parity (1, 2, 3, and ≥ 4). By the onset of the present study (September/October 2002), 18 study animals per farm remained for behavioural observations (in each herd, two animals had been culled in the meantime).

Table 1. Farm characteristics of the study herds.

	Herd A	Herd B	Herd C	Herd D
Housing type	Cubicle house	Cubicle house	Cubicle house	Straw yard
Floor type	Slatted concrete	Solid concrete	Grooved concrete	Straw/slatted concrete
Milk production1	8700	8300	8000	7100
Number of cows	70	47	65	38

[1] kg milk/cow/year

Lactating cows in the cubicle houses had access to two rows of cubicles with a concrete passageway in-between. The cow : cubicle ratio was 1 : 1. The feeding rack was separated from the cubicles by a concrete passageway. The straw yard consisted of a straw-bedded area with a slatted floor in front of the feeding rack. The four herds were milked twice a day, with starting time varying between 06.00 and 08.00 and 16.30 and 18.00. Cows in all herds were fed *ad lib* on silage-based diets (grass : maize ratio varying between 50-70% : 30-50%) and concentrates were supplied depending on cow's production level. Fresh feeding was administered twice daily around the time of milking. Cows had their claws trimmed two weeks before the start of the behavioural observations.

Behavioural observations and measurements

At each farm, four video cameras were installed inside the cow building that covered the complete lactating-herd area (except for the milking parlour). A video quad system (EQM 100) was used to consolidate the cameras' output into one picture. A video switcher cycled between the four cameras producing a 15 seconds full screen picture per camera within every 60 seconds. Both pictures were recorded by time-lapse video recorders (used in 72 h time mode). Recordings were made 14 days after claw trimming at the start of housing, and 3.5, 4.5 and 5.5 months after trimming.

Each observation period consisted of two consecutive 24-hr periods. In the cubicle-housed herds, the behaviour of the individual cow was scored at 15-min intervals (96 observations per 24 hours). Main behavioural activities scored were: 1) lying in cubicle, 2) standing in/half-in cubicle, 3) standing/walking in concrete passageway, 4) feeding and

drinking, and 5) milking. The study cows in the cubicle-housed herds were identified with yellow fabric halters and photographs were taken to facilitate cow identification.
In the straw-yard herd, behavioural activities were not individually scored (motivated in section 'Data analyses'). Instead, the number of animals 1) lying in the straw-bedded area, 2) standing or walking in the straw-bedded area, 3) standing/walking in concrete passageway, 4) feeding and drinking, and 5) milking was recorded at 15-min intervals.

Claw and locomotion observations

At one day prior to each video observation, hind claws were examined for lesions of DD. Presence and severity of DD was scored on a scale of 0 to 2, according to the system developed by Döpfer (1994): M0 = no clinical symptoms; M1 = early stage with a circumscribed granulomatous area, lesion 0.5 to 2 cm in diameter; M2 = classical ulceration, lesion more than 2 cm in diameter. The sum of DD score in left and right hind leg was categorized as follows: 1 = Negative (M0 in both legs); 2 = Slight (M1 in one or both legs); 3 = Moderate (M2 in one leg, 0 in the other); 4 = Severe (M2 in one leg and score M1 or M2 in the other).

After each claw examination, the locomotion of an animal was assessed while walking in the concrete passageways. Locomotion was observed from behind so that the degree of ab/adduction of hind limbs, unevenness in gait, and abnormal weight bearing could be gauged. We used a simplified 4-point locomotion score derived from the frequently used scoring system by Manson and Leaver (1988). Our adjusted scoring was as follows (see Table 2): 1 = Normal (no/minimal unevenness of gait); 2 = Tenderness (uneven gait, clear ab/adduction in limbs); 3 = Slight lameness (asymmetry, abnormality in weight-bearing); 4 = Severe lameness (unwilling to move and bear load upon the affected limb, 'walking on three limbs'). The first author carried out all scoring to avoid inter-observer variation.

Data analyses

Analysis showed no difference in behavioural activities between the two consecutive 24-hr recordings (data not shown). Hence, the data from day 1 and 2 were pooled. The total time per activity was calculated and expressed in minutes/24 hr. The total time per activity was also calculated for day (06.00 to 18.00 hr) and night period (18.00 to 06.00 hr). For the cubicle-housed herds, the average bout duration (duration of successive 15-min periods in which the activity of a cow had not changed) and bout frequencies were calculated.

The effects of locomotion score, DD, herd, observation period, and interaction between herd and observation period on main behavioural activities in cows kept in cubicle houses were studied with a mixed linear model allowing for random effects of animal and herd (SAS, 1996). Lame cows and cows affected by DD were absent in the straw-yard herd. One-way ANOVA was performed to test mean differences in time budgets between groups of non-lame cows in the straw yard, and lame and non-lame cows in the cubicle houses. Differences were considered to be significant at $P < 0.05$ unless otherwise stated.

Table 2. Explanation of locomotion score used in the present study and derived from the scoring system developed by Manson and Leaver (1988).

	LOCOMOTION SCORE	
Locomotion characterization	Manson and Leaver	Present study
Minimal abduction/adduction, no unevenness of gait, no tenderness	1.0	1
Slight abduction/adduction, no unevenness of gait, no tenderness	1.5	1
Abduction/adduction present, uneven gait, perhaps tender	2.0	1
Abduction/adduction present, uneven gait, tenderness of feet	2.5	2
Slight lameness, not affecting behaviour	3.0	3
Obvious lameness, difficulty in turning, not affecting behaviour	3.5	3
Obvious lameness, difficulty in turning, behaviour affected	4.0	4
Some difficulty in rising, difficulty in walking, behaviour affected	4.5	4
Extreme difficulty in rising, difficulty in walking, behaviour affected	5.0	4

RESULTS

Effect of locomotion score

Total time spent per main activity (lying in cubicles, standing in cubicles, feeding), bout duration and number of bouts are shown in Table 3. There were significant effects of locomotion score on lying behaviour ($P < 0.03$) and total feeding time ($P < 0.03$), while the effect of observation period was non-significant. The interaction between herd and observation period was significant in the model with total feeding-time as dependent variable. Slightly and severely lame cows had longer lying bouts than those that walked normally or with tenderness (slightly lame vs. normal, $P = 0.07$), but had fewer bouts per day. Hence, the groups did not differ in total lying time. Severely lame cows showed fewer feeding bouts than the other groups, resulting in reduced total feeding time.

No differences in day- and nighttimes per main activity were found between the locomotion groups (Table 4).

Effect of DD

There were significant effects of DD ($P < 0.03$) on lying behaviour and total time standing in cubicles ($P < 0.03$) (Table 3). Severely affected animals had fewer lying bouts per 24 hr than others (severely vs. slightly affected, $P = 0.08$), resulting in reduced total lying time. The reduction in lying time is visible during daytime (Table 4). Per 24 hr and during the night, severely affected animals stood for longer periods in cubicles than others (severely vs. slightly affected in 24 hr-period, $P = 0.07$) (Table 3 and 4).

Table 3. Least square means (± S.E.M.) of total time spent, bout duration, and number of bouts per main behavioural activity in dairy cows kept in cubicle houses with varying locomotion score and lesion score for digital dermatitis.

	LOCOMOTION SCORE				DIGITAL DERMATITIS			
Cow activity	Normal	Tender	Slightly lame	Severely lame	Negative	Slight	Moderate	Severe
Total lying time[1]	592±18.5	606±23.7	614±24.9	631±38.5	643±21.2	645±28.2	621±24.6	534±23.5[a]
- Mean lying bout[2]	101±5.0[bc]	94±6.8[b]	118±7.0[ac]	130±10.9[a]	109±5.8	112±8.3	104±7.0	118±6.5
- Number of bouts	6.5±0.3	6.6±0.3	5.5±0.4[a]	5.0±0.6[a]	6.3±0.3[a]	5.9±0.4[ab]	6.2±0.4[a]	5.5±0.3[b]
Time spent standing in cubicles[1]	179±15.5	173±20.1	177±21.1	226±32.5	170±17.9[a]	185±24.0[ab]	165±20.8[a]	236±19.8[b]
- Mean standing bout[1]	28±1.5	28±2.0	30±2.1	37±3.3	29±1.8	30±2.4	30±2.1	34±2.0
- Number of bouts	5.8±0.4	5.8±0.5	5.9±0.5	5.6±0.8	5.6±0.4	5.8±0.6	5.3±0.5	6.4±0.5
Total feeding time[1]	307±8.1	297±10.7	288±11.1	245±17.2[a]	287±9.3	272±12.9	288±11.0	288±10.4
- Mean feeding bout[2]	30±0.9	30±1.2	31±1.2	34±1.9	32±1.0	32±1.4	30±1.2	32±1.1
- Number of bouts	10.5±0.4	9.8±0.4	9.5±0.5	6.9±0.7[a]	8.9±0.4	8.6±0.5	9.5±0.5	9.8±0.4
Number of observations	114	53	66	22	104	33	51	67

Within-row values for locomotion score or digital dermatitis score with different superscripts differ significantly ($P < 0.05$).

[1] minutes/24/hr

[2] minutes

Table 4. Least square means (± S.E.M.) of time spent during the day and at night per main behavioural activity in dairy cows kept in cubicle houses with varying locomotion score and lesion score for digital dermatitis.

	LOCOMOTION SCORE				DIGITAL DERMATITIS			
Cow activity	Normal	Tender	Slightly lame	Severely lame	Negative	Slight	Moderate	Severe
Lying time:								
- During the day[1]	264±10.2	257±13.3	271±13.9	283±21.5	276±11.7	275±16.0	274±13.8	250±13.0
- At night[2]	333±11.8	347±15.5	342±16.2	346±25.3	366±13.6	366±15.5	345±16.0	292±15.2[a]
Time standing in cubicles:								
- During the day[1]	69±7.0	72±9.3	76±9.7	99±15.0	72±8.1	829±11.3	66±9.6	95±9.0
- At night[2]	108±10.1	102±12.9	103±13.6	130±20.9	98±11.6	103±15.4	99±13.4	143±12.8[a]
Feeding time:								
- During the day[1]	163±6.0	165±7.7	152±8.1	132±12.5	159±6.9	145±9.1	152±8.0	157±7.8
- At night[2]	146±5.6	132±7.3	136±7.6	114±11.8	127±6.4	126±8.8	135±7.6	139±7.1
Number of observations	114	53	66	22	104	33	51	67

Within-row values for locomotion score or digital dermatitis score with different superscripts differ significantly ($P < 0.05$).

[1] minutes between 06.00 and 18.00 hr

[2] minutes between 18.00 and 06.00 hr

Effect of housing and lameness

Mean time budgets in non-lame cows in the straw-yard herd (**NLS**), and non-lame (**NLC**) and lame (**LC**) cows in the cubicle-housed herds are presented in Figure 1. NLS cows lay down for significantly longer periods (744 min/24 hr; $P < 0.01$) than NLC (607 min/24 hr) and LC (605 min/24 hr) cows. LC cows spent the most total time standing in cubicles (236 min/24 hr, $P < 0.01$), while NLC cows stood as long in cubicles than NLS cows in the straw-bedded area (143 and 142 min/24 hr, respectively). LC cows tended to have longer milking times (includes staying in-front and inside milking parlour) than non-lame cows, either in the straw yard (+ 25 min; $P = 0.05$) or cubicle houses (+ 18 min; $P = 0.05$). NLS cows spent significantly less time in the concrete passageway compared to both NLC (+ 113 min; $P < 0.01$) and LC cows (+ 80 min; $P = 0.01$).

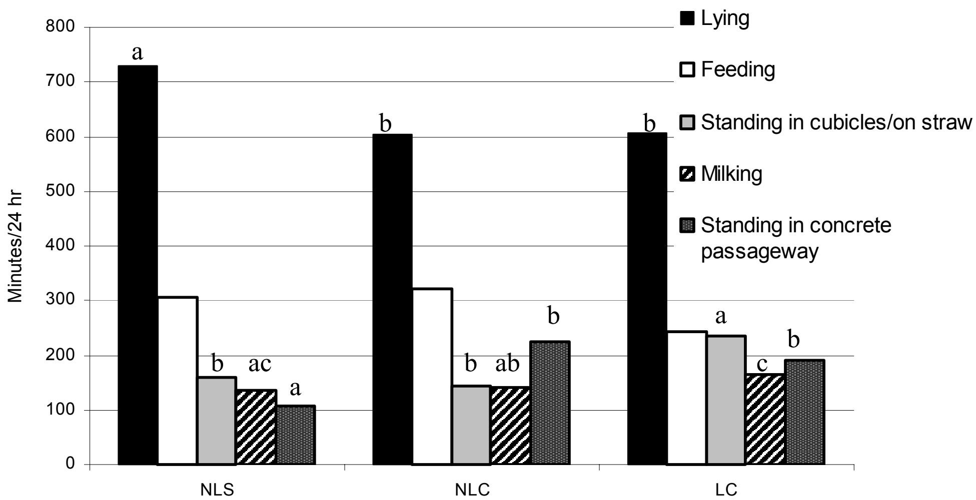

Figure 1. Differences in mean time budget between groups of non-lame cows in a straw yard (NLS), non-lame cows in cubicle houses (NLC), and lame cows in cubicle houses (LC). Bars indicating similar behavioural activity with different letters above differ significantly ($P \leq 0.05$).

DISCUSSION

In a previous study, we found that lesions of DD caused significant disturbances in cow locomotion (see Chapter 6). The present study is the first that assessed the effect of DD on cow behaviour. Severely affected cows altered their time budget apparently to cope with the disorder and associated pain. Those animals stood for longer in cubicles, and had reduced total lying time due to fewer lying bouts. Reluctance to lie down in order to avoid pain and discomfort might be the cause for this change in behaviour. While lying down and getting up in particular, much pressure is applied to the skin surrounding the claw and thus also to the DD-affected spot. Avoidance of lying behaviour is then a likely outcome. Lame animals also were less willing to lie down (i.e. fewer lying bouts), but they remained lying down for significantly longer (increased bout duration), probably because of reluctance to stand up. Per 24 hr, slightly and severely lame cows reached similar lying times as non-lame cows. This result is inconsistent with behavioural studies that pointed to increased lying times in lame cows (Hassall et al., 1993; Singh et al., 1993; Juarez et al., 2003).

Lameness significantly reduced the number of feeding bouts and the total feeding time. Shorter feeding time due to reduced mobility was also reported by Hassall et al. (1993) and Juarez et al. (2003). In coherence with those authors, we found also that lame cows waited longer before entering the milking parlour than non-lame cows, and therefore had longer milking times. Animals with reduced mobility are probably pushed away more easily by herd mates. The prolonged waiting on their painful limb(s) is an extra source of discomfort. Another aspect is that by the time these animals return from the milking parlour, there is more competition at the feeding rack. The quantity and quality of feed available for the lame animals may also be lower than it was for the earlier-milked cows (Juarez et al., 2003). Reduced feed intake is a logical consequence of the foregoing. A wide variability of milk production responses to lameness has been reported in literature (Green et al., 2002). In lame cows that show no (Rowland and Lucey, 1986; Barkema et al., 1994) or relatively low loss of milk production of around 1 kg per lactation day (Rajala-Schultz et al., 1998; Warnick et al., 2001), reduced feed intake is likely at the expense of cow's body condition. Structural losses of body condition and body weight in lame cows have been demonstrated by Esslemont (1990) and Tranter and Morris (1991).

Our results are supported by work from others, also indicating that cows in straw yards have longer lying time per day and spent less time in concrete passageways than cows kept in cubicle houses (Fregonesi and Leaver, 2001; Phillips and Schofield, 1994). The first behavioural difference is most likely due to a more comfortable lying facility: a soft and resilient underground, without physical restrictions for lying-down and standing-up behaviour. The average lying time of 13 hours in our straw-yard herd comes close to the ideal resting time of 13 to 14 hours as suggested by Wierenga and Hopster (1990). The second behavioural difference is not surprising because of the reduced concrete surface in a straw-yard system. However, as the straw-bedded area provides a dry and soft foot environment, which is beneficial for claw health and weight bearing, cows prefer standing on straw instead of concrete while ruminating or idle-standing (Fregonesi, 1999).

CONCLUSIONS

Lameness caused significant disturbances of lying and feeding behaviour. In addition, classical lesions of digital dermatitis induced disturbances in cow behaviour such as reduced lying time and prolonged cubicle-standing. The straw yard provides better opportunity for cows to perform normal behavioural activity than cubicle houses.

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Chapter 8

General Discussion

Disturbed locomotion and claw disorders are recognised as an important animal welfare problem at dairy farms. Affected animals may suffer from pain, chronic discomfort, insecure and reduced mobility, which ultimately leads to behavioural suppression. Evidently, this has consequences for the cow's well-being. Since claw and locomotor disorders are frequently diagnosed in modern managed dairy herds in many countries, there is an urgent need for measures that contribute to solving or reducing the problem.

The main question underlying this thesis was stated as "what can be improved from the side of the cow's living environment, i.e. housing and flooring design in particular, to promote unrestricted locomotion and healthy claws?" For the answer, a multidisciplinary research was conducted into epidemiological and ethological aspects of claw disorders and disturbed locomotion. Two descriptive and analytical studies were conducted in dairy herds in The Netherlands, i.e. a cross-sectional (Chapter 2, 3, 4) and a longitudinal study (Chapter 5, 6, 7). Performing observational studies in the field is an efficient way to test associations between disease and exposure to presumed causal factors under practical circumstances and at large scale (Frankena and Thrusfield, 1997).

The main goal of our research was 1) to show in quantitative terms to what extent Dutch dairy cows kept on several floor systems show disturbed locomotion and claw disorders, and 2) to investigate the effect of disturbed locomotion and claw disorders on cow behaviour, to assess the impact on animal welfare. Both environmental and farm-management factors were investigated. Ultimately, information in this thesis should contribute to a cow-environment and farm-management practice that reduce the levels of disturbed locomotion and claw disorders, and thus facilitate unrestricted locomotion.

MAIN FINDINGS

Our cross-sectional study showed that nowadays the majority of dairy cows in The Netherlands have one or more claw lesions. Most prevalent disorders were interdigital dermatitis and resulting heel erosion (IDHE), digital dermatitis (DD), and sole haemorrhages. However, marked contrasts in prevalences were found between the cubicle houses with concrete passageways and straw-yard systems. Cows in straw yards were the least likely to develop claw disorders. Within the cubicle house types, cows kept on a scraped slatted floor were less likely to show digital lesions such as DD and IDHE. (**Chapter 2**). Apart from cow characteristics (i.e. parity, stage of lactation), various herd-level factors related to housing facility, pasturing, farm and claw-care management were identified that could reduce the prevalence of DD and IDHE (**Chapter 3 and 4**).

The hypothesis underlying our longitudinal study was that floor-related differences in claw health are attributable to differences in horn growth and wear and resulting claw shape. We found that type of flooring (either slatted, solid, grooved concrete or straw-yard system) had only limited effect on claw horn production and physical claw characteristics such as dimensions and horn hardness. Supplementary to the 'snap-shot' taken in the cross-sectional study, development of DD and IDHE lesions was followed in-depth in the cows in the longitudinal study. DD is a long-lasting disorder that was most prevalent in cubicle- than in straw-yard-housed cows. Affected cows cured poorly. Especially, classical DD lesions were rather insensitive to claw trimming and frequent use of footbathing. Lesions of IDHE progressed gradually over time, irrespective of floor type. Associated heel horn damage can be adequately treated by corrective claw trimming (**Chapter 5**).

Serious lesions of DD and IDHE highly affected locomotor performance and caused significant gait disturbances. Locomotion was significantly better for cows kept in straw yards compared to cows kept in cubicles houses with concrete passageways. The vast majority of straw-yard housed cows showed no abnormality while walking, but half of the cubicle-housed cows showed either tender or disturbed locomotion. Moreover, recovery from lameness was poor as disturbance in gait often endured for several months (**Chapter 6**). Data-analysis on 24-hr time budgets among healthy and affected animals in cubicle houses revealed that cows affected by severe DD spent significantly less time lying down in favour of prolonged time standing in cubicles. Feeding times were significantly reduced in severely lame cows. Non-lame cows housed in straw yards lay down for about 12 hours per day; an increase of more than two hours compared to non-lame cows in cubicle houses. The reduced lying time is mainly spent to standing and walking on concrete floors, which may contribute to the housing-related differences in claw and locomotor health (**Chapter 7**).

ASSOCIATED FACTORS

Claw and locomotor problems have a multifactorial background. Research over the past 20 years suggests a variety of causal factors, which can be broadly classified into environmental (e.g. housing, nutrition, management) and animal-related (e.g. breed, production) factors. The physical environment, i.e. housing and flooring in particular, has been the main focus in the present work. Manifestation of locomotor and claw disorders was less-frequent and less-severe in straw yards than in cubicle houses with concrete passageways. The next section (Impact on welfare) goes more deeply into the benefits of comfortable walking and lying surfaces from the perspective of establishing healthy claws and normal locomotion in dairy cows.

In literature, feeding has primarily been correlated with the development of sole haemorrhages, or subclinical laminitis (reviewed by Greenough and Weaver, 1997). Others, however, have doubts about the role of nutrition as primary cause for sole haemorrhages (Logue et al., 2004). In biomechanical work by Van der Tol (2004), it was concluded that adverse claw-(concrete) floor interaction may highly contribute to the development of claw horn lesions. This was supported in our cross-sectional study, as the prevalence of sole haemorrhages was lower in cows kept in straw yards than in cubicle houses (Chapter 2). In general, mainly mild manifestations of haemorrhagic lesions were found. Hence, this type of lesion has been considered of less importance in The Netherlands than is reported for other countries (reviewed by Vermunt (2004)). Under Dutch conditions, infectious digital lesions (i.e. IDHE, DD, interdigital phlegmon and resulting interdigital hyperplasia) are predominantly responsible for claw and locomotion problems in dairy herds. Environmental factors rather than nutritional elements are contributive to the development of these lesions, and hence have been the focus in this thesis.

It is commonly found that first-calving heifers around the time of parturition are at highest risk for developing lameness due to claw horn lesions (e.g. Kempson and Logue, 1993; Leach et al., 1998; Livesey et al., 1998; Webster, 2001). In our cross-sectional survey, it was shown that first-parity cows were most susceptible for having DD (see Chapter 2). Due to our study design (cross-sectional), we gained no insight into interdigital phlegmon, which is also commonly seen in heifers. Prevention of lameness at young age is essential because of higher susceptibility in the future. First-parity cows that become lame are two to three times more likely to develop lameness also during following lactations (Ward and French, 1997; Hirst et al., 2002).

Production capacity is another cow characteristic that may influence susceptibility for claw and locomotor problems. Studies are available that associate increased milk yield with an overall decline in claw health (Fourichon et al., 2001; Manske, 2002). In our study, individual milk yield was not related to DD and IDHE (Chapter 3 and 4). A genetic predisposition may be involved in the aetiology since cows from breeds other than the traditional Holstein-Friesian are less susceptible to certain claw disorders (Peterse, 1985; Alban, 1995; Huang et al., 1995). On the other hand, there is large degree of within-breed variation that may be due to individual heritable resistance (Toussaint-Raven and Cornelisse, 1971).

IMPACT ON WELFARE

Welfare can be defined as the state of animals regarding their attempts and ability to cope with their environment (Broom, 1996). The ability of cows to cope with loose-housing facilities highly depends on the adaptive capacity of the claw capsule and locomotor apparatus. Unrestricted and painless locomotion is crucial for cows in loose houses to successfully satisfy their biological and social needs (Metz and Bracke, 2003). Scientists and governments in several countries have expressed a growing concern about actual levels of claw and lameness problems (e.g. RDA, 1996; FAWC, 1997). Particularly for animal welfare reasons, their concern is completely in place. Claw lesions are often a source of pain and discomfort to cows. An aberration of locomotion is then a likely outcome as was clearly proven in Chapter 6.

Disturbed locomotion is an useful behavioural indicator for the degree of pain and discomfort caused by claw disorders (Whay et al., 1998). In our longitudinal study, on average a quarter of the cows in cubicle houses showed disturbed locomotion, and another quarter walked tenderly (Chapter 6). In particular DD has been identified as an important factor contributing to (painful) restricted movement, further enhanced by its apparent chronic course (Chapter 5). A practical and optimal treatment and pre-/intervention strategy has not been developed so far. During the last decade, the situation regarding DD has even strongly deteriorated and the condition has become more widespread among and within dairy herds in The Netherlands during the last 10 years; i.e. indicated by a three-fold increase in mean cow-level prevalence (~30%; see Chapter 2). Of all cows lame due to DD, the majority expressed slight to moderate lameness (Chapter 6), and thereby contrasting other lesions such as interdigital phlegmon, sole ulceration, and white line disease that generally lead to obvious lameness (Clarkson et al., 1996). Nevertheless, welfare implications due to DD might be considered of greater importance since the condition is often persistent for several months (Chapter 5), and so is the consequent disturbance in locomotion (Chapter 6). Moreover, DD interfered with behavioural activity (Chapter 7). Severely affected cows lay down for 1.5 hr less per day than cows without any symptoms of DD or only slightly affected ones. The prolonged time standing in cubicles (and thus avoidance of lying behaviour) might be interpreted as coping strategy to reduce pain caused by DD during lying-down and getting-up behaviour.

POSSIBILITIES FOR IMPROVEMENT

Improvements in housing

The above-discussion points to the urgency to reduce the occurrence of locomotor and claw disorders in dairy farming. Ideally, a cow-environment should be provided that promotes unrestrained locomotion, keeps cows healthy, and in which the animal is able to adequately cope with adverse situations. No husbandry system is perfect. The challenge is to create a livestock environment with a better balance between cows' needs on the one hand and working conditions and economic factors on the other hand.

The cow-living environment comprises several elements. Dairy cows in Northern Europe are generally at pasture during the summer and housed in the winter for climatological reasons. Over the last decade, however, an overall decline in pasturing is seen in dairies in The Netherlands (see Chapter 1). The importance of pasturing for claw-health reasons has been underlined in Chapter 2, 3, and 4, as the risk of having claw disorders was found to decrease with increasing time spent at pasture. This agrees with other studies in which the housing period has been associated with impaired claw and locomotor health compared to pasture season (Frankena et al., 1991; Leonard et al., 1994). The current trend of increased housing makes a critical evaluation of the housing requirements of animals of even greater importance.

Straw yard is undeniably the most favourable housing system regarding claw and locomotor health as can be concluded from our research (Chapter 2 and 6). Prevalence of several claw disorders and associated lameness was drastically lower in straw yards than in cubicle houses with concrete passageways. As a consequence, the system highly facilitated unrestricted locomotion (on average 80% of the cows walked normally vs. 50% in cubicle houses). The benefit of a straw-yard system includes both a mechanical-buffing walking surface as well as a softer lying area. But to what extent locomotor performance was improved by the comfort of longer lying (i.e. resting and recovery time) (see Figure 1 in Chapter 7), and to which part to less mechanical stress on the claws of cows in the straw-bedded area, cannot be decided without closer experiments. Recently, biomechanical work gave further support to the hypothesis that the claw-concrete floor interaction and associated adverse load bearing contribute to the development of claw disorders (in particular claw horn lesions and haemorrhages) and restrained locomotion (Van der Tol, 2004). In the early-seventies, it was already shown that weight bearing in hind limbs while standing on concrete is mainly subjected to the lateral claw (Toussaint-Raven, 1973). At walk, however, total load applied to that claw is about twice as high (Van der Tol et al., 2003). Concrete is an extreme hard and unyielding surface, since the material hardly deforms under loading. Total load pressures exerted during the contact between the bovine heel and the concrete surface underneath are hence fully absorbed by the bovine claw, which might damage the internal claw structure - fat pad cushion in particular (Logue et al., 2004) – having a kind of inflammatory reaction as potential outcome. The contribution of claw-floor interaction in the development of claw disorders and impaired locomotion might be reduced by application of mechanical-buffing underground (e.g. rubber-covered, straw bedding, soil) (Benz, 2002; Van der Tol, 2004). Softer floors enable a more-natural load bearing within the claw, resulting in reduced vulnerability for claw disorders and better locomotion (Hultgren and Bergsten, 2001; Benz, 2002; Telezhenko and Bergsten, 2003). Use of rubber mats on concrete floors is still under development. But many questions towards design and consequences of rubber-covered floors are unanswered so far. These questions are related to the type of material that is optimal in terms of cow comfort, durability, and cost price, to the proportion of the total concrete surface should be covered, to the extent horn growth and wear and consequent claw shape are influenced by soft, buffing surfaces. Clear answers tot these questions are needed prior to a large-scale introduction of rubber-coated floors in the field.

Concrete floors also restrict normal locomotion for other reasons than its hardness. Slippery floors, for example, result in smaller movement amplitude of cows' proximal joints and reduced velocity at walk (Phillips and Morris, 2001). Also shorter stride length has been reported (Telezhenko et al., 2002). Wetness of the floor surface from the presence of slurry provokes the unnaturalness of gait, and forces the cows to adapt their locomotory behaviour (Albutt et al., 1990; Phillips and Morris, 2000). Recently, it has been demonstrated that concrete floors provide insufficient friction to allow unrestrained locomotor behaviour. Straight walking and walking-a-curve (e.g., at the end of the passageway or when by-passing other cows) in dairy cows occurred at the limit of surface-provided frictional forces, while for sudden stop- and start movements that limit was exceeded, potentially resulting in slipping and injuries (Van der Tol et al., in press). Lack of traction seems to be a clear explanation for reduced expression of oestrus behaviour and self-care activities (e.g. caudal licking) in cows kept on concrete floors (Benz, 2002). Cows feel unconfident at slippery floors and refrain from 'risky' behavioural activities. To decrease the risk of slipping, mechanical grooving and tamping of different patterns in concrete passageways are used to improve roughness (Albright, 1995; Phillips et al., 1998; Swierstra et al., 2001). Such measures, however, have the adverse effect of locally inducing high-pressure concentrations underneath the claw (De Belie et al., 2002). Another solution is to increase dryness of the floor environment, for instance by automatic scraping and better barn ventilation. This may also reduce the risk for infectious claw disorders such as DD, IDHE, and interdigital phlegmon.

Dairy cows lie down to rest for about 10 hours a day when housed. An ideal resting place has been described as a comfortable, clean and dry lying area that is easily approachable (often referred to as "cow-comfort"). Cow can stand up and lie down without difficulty and rest comfortably, in security and in social contact with each other (Webster, 1986). It is known by preference tests that cows choose lying in a straw yard above lying in cubicles (Nilsson, 1992; Fregonesi, 1999). Straw yards are generally better suited for lying than cubicles, and hence more time is spent lying down: approximately 2 hours per day (Singh et al., 1994). If cows lie longer, the duration of claw-floor contact decreases, which prevents lameness (Bergsten, 1995; Scott, 1996). Moreover, less time standing in slurry probably decreases the risk of infection (Bergsten and Pettersson, 1992). The design of resting places in cubicle houses may provide a solution in lowering the prevalence of claw disorders. It has been suggested earlier that base and bedding of the cubicle have a profound effect on cow's lying time (Greenough, 1991). Cubicles provided with a resilient and soft lying surface (deep straw, cow-mattress) may increase daily lying times up to 14 hours, i.e. similar lying times as at pasture and in straw yards (Cermak, 1982). Our cross-sectional study revealed that comfortable cubicles, in terms of greater dimensions, reduced the risk of cows having lesions of DD and IDHE (Chapter 3 and 4). There was no effect of thickness of bedding material on the level of claw disorders in cubicle houses, which is contrary to a British survey that concluded that lameness and poor locomotion were strongly related to poor bedding, incorrect cubicle dimensions, kerb-height, and placement of head-rail (Faull et al., 1996).

Dairy cattle are social animals that operate within a herd structure (Albright and Arave, 1997). For example, eating and lying behaviour are commonly performed in groups while at pasture. Synchronization in lying-behaviour happens more in straw yards than in cubicle houses (Fregonesi and Leaver, 2001). This is in coherence with their innate habits, and therefore can be considered as having a positive effect on animal well-being. Furthermore, and besides the potential benefits with regard to claw and locomotor health (Chapter 2 and 6), straw yards may be economically interesting because of lower building costs, sale of a high-grade manure-product, and reduced financial loss from lameness. On the other hand, one must be aware of the potential risk of udder diseases. It is therefore important to secure hygiene in the bedded area to a large degree by daily adding sufficient amounts of fresh straw (Fregonesi and Leaver, 2001). Another perceived disadvantage of straw yards is the extra labour necessary for scattering bedding material twice a day. However, automatic straw-scattering devices for straw-bedded barns are purpose-built, and checking of cubicles and manually providing sawdust in cubicles also costs time.

Improvements in management

Apart from improvement in housing, farmers can reduce the amount of claw disorders and disturbed locomotion within their herd by certain management measures (see Chapter 2, 3, and 4). Possible reduction by unlimited pasturing in the summer and better indoor-floor hygiene (e.g. manure scraper) has already been discussed in the housing-section. Farmer's policy towards claw trimming, use of footbaths, monitoring and individual treatment is also important in this respect.

Usually, hind claws of dairy cows in The Netherlands are routinely trimmed once or twice a year. Applying herd trimming at shorter intervals can help controlling claw disorders and prevent development into disturbed locomotion. From the results as described in Chapter 3 and 4 we learned that cows are more likely to develop serious lesions of DD and IDHE if the time period between two herd trimmings exceeded 7 months. Furthermore, locomotion deteriorated with progressing time after trimming (Chapter 6). Corrective trimming is aimed at restoring normal shape for functional load bearing. Nevertheless, trimming is no guarantee for unrestricted locomotion (Chapter 6). Firstly, because animals still have to deal with adverse flooring conditions (i.e. concrete, wet, slippery). Another reason is that the force balance between lateral and medial claw is just slightly improved by corrective trimming; the highest pressures were unaltered high and still located at the bulb area, i.e. weakest part of the claw in terms of breaking strength (Van der Tol et al., 2004). It was concluded that trimming should focus on distribution of high pressures to stronger parts of the bovine claw (i.e. the wall) rather than an equal force balance. The present Dutch trimming method was developed some 20 years ago (Toussaint-Raven et al., 1985). Scientists from the UK suggested in this respect that there may be a need to re-adjust trimming techniques after such an extended time-period and associated changes in dairy breeds and production systems (Logue et al., 2000).

Use of a footbath is a commonly used method to control infectious lesions with varying success, either because of inappropriate use and dirtiness or choice of substances (Chapter 3, 4 and 5). For example, formalin-footbath is effective in reducing presence and severeness of IDHE (Peterse, 1980), but ineffective with regard to DD. The latter requires antibiotic solutions (Bergsten, 1997; Manske et al., 2002), but use in footbaths is banned in The Netherlands. Currently, copper and zinc sulphate are popular as alternatives for antibiotics. Use of heavy metals, however, is not desirable because of pollution of agricultural grounds. As long as no adequate footbath-substance is available, individual (topical) treatment of DD lesions with antibiotic spray is the alternative (Blowey, 1990; Bergsten, 1997). Farmers dislike individual treatment because it is very labour-intensive, but probably the best way to cure animals from DD.

Ideally, farmers diagnose claw disorders at an early stage. This will likely increase success of treatment and prevent that affection(s) will progress into disturbed locomotion. In practice, action is usually taken when a claw disorder becomes visually at movement; those animals that show disturbed locomotion are treated. Furthermore, the interpretation of 'disturbed' locomotion varies widely among farmers. Farmers are rather insensitive to the actual level of lameness in their dairy herds (Mill and Ward, 1994; Whay et al., 2002). Generally there is a variable degree and/or duration of lameness before any action is taken, especially in case of slight to moderate disturbance. An UK study estimated the average duration of a lameness case at 140 days (Clarkson et al., 1996). Also in our study, lameness often endured for several months (see Figure 3 in Chapter 5), mostly due to the fact that animals were simply not treated, especially those who were slightly/moderately lame. This is either because a (visible) deflection is judged as normal, or farmers dislike individual treatment because it is labour-intensive. Lack of suitable conditions for observing cows' gait might be another explanation for underestimation of lameness (Wells et al., 1993). Lameness detection is commonly done by observing the herd at milking time. The situation around milking is rather inconvenient for monitoring deviations in gait. A close look at the locomotion of individual animals (ideally, but impractically, at various moments during the day,) might be more successful to detect signals reflected by affected cows, such as arched back posture, alteration in weight bearing, resulting in asymmetry at walk and reluctance to move.

MAIN CONCLUSIONS

This study reveals that disturbed locomotion and claw disorders represent a main animal welfare problem in present Dutch dairy farming. Main conclusions of the thesis are:

- Dairy cows in The Netherlands, especially those kept in cubicle houses, are highly troubled by disturbed locomotion and claw disorders.
- Chronic claw-skin lesions of digital dermatitis and interdigital dermatitis/heel erosion are the most prevalent symptoms, and are the main cause for disturbed locomotion in dairy cows. The prevalence of digital dermatitis has more than doubled in the past 10 years.
- Lameness and digital dermatitis reduce cow mobility with obvious consequences for lying and feeding behaviour.

- Farm-related measures to reduce digital dermatitis and interdigital dermatitis/heel erosion include 24-hr pasturing in the summer, floor hygiene by automatic manure-removal, comfortable lying places, herd trimming at relatively short intervals, regularly use of (formalin-) footbath, and individual topical treatment of digital dermatitis.
- Straw yards are more favourable than cubicle houses with regard to claw health, locomotion and cow behaviour. Cows kept in straw yards are less exposed to unfavourable floor conditions so that a vast majority of straw-yard cows walk normally, irrespective of having slight and moderate digital lesions.
- Application of mechanical-buffing floors in cubicle houses may contribute to reduction of disturbed locomotion and claw disorders.

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Samenvatting

Klauwaandoeningen en gestoorde locomotie bij melkkoeien: de invloed van vloersystemen en implicaties voor dierwelzijn

Gestoorde locomotie en klauwaandoeningen bij het rund leiden tot verstoring van het dierwelzijn. Dieren ondervinden pijn, zijn beperkt bij het uitvoeren van hun gedrag en worden daarmee belemmerd in het voorzien van hun biologische behoeften. De omgeving waarin koeien gehuisvest zijn speelt een belangrijke rol bij het ontstaan van klauwgebreken en gestoorde locomotie. Van de huidige 1,5 miljoen melkkoeien in Nederland wordt ongeveer 80% gehouden in een ligboxenstal met betonnen stalvloer. Verreweg de meeste dieren lopen op een roostervloer, al dan niet voorzien van een automatische schuif om mest en urine te verwijderen. Anderen lopen op een dichte, vlakke vloer of een (emissie-arme) sleufvloer. Een klein deel van de koeien in ons land wordt gehouden in een potstal. Dit huisvestingssysteem bestaat uit een groot ligbed van stro, vaak in combinatie met een betonnen loopgang achter het voerhek. Met name de betonvloer in ligboxenstallen wordt gezien als een belangrijke veroorzaker van gestoorde locomotie en verschillende klauwaandoeningen. Deze ondergrond is hard, terwijl koeien van nature gewend zijn zich op een zachte bodem (weide) te bewegen. Daarnaast zorgt de aanwezige mest en urine op de vloer dat koeienklauwen vatbaarder worden voor infectieuze klauwaandoeningen. Een natte vloer is ook vaak een gladde vloer, met het gevaar van uitglijden als de dieren actief zijn. Kortom, vanuit het dier gezien zijn de nodige bezwaren te noemen ten aanzien van de huidige stalvloeren op melkveebedrijven.

De doelstelling van dit proefschrift is om inzicht te krijgen in de mate waarin klauwaandoeningen en gestoorde locomotie voorkomen in de Nederlandse melkveehouderij, in hoeverre dit beïnvloed wordt door het type stalvloer, en wat het effect is op het gedrag van koeien, als maatstaf voor dierwelzijn. Hiertoe zijn achtereenvolgens een epidemiologisch dwarsdoorsnede-onderzoek (hoofdstuk 2, 3, 4) en een longitudinale epidemiologische/ethologisch studie (hoofdstuk 5, 6, 7) uitgevoerd op melkveebedrijven. Op grond van kennis uit dit project wordt verwacht dat de praktijk kan komen tot aanpassingen en preventieve maatregelen op het gebied van huisvesting en management, ter verbetering van de klauwgezondheid en locomotie.

In **Hoofdstuk 2** wordt de klauwgezondheid op verschillende stalvloeren vergeleken. Tijdens klauwbekappingen op 86 melkveebedrijven zijn de achterpoten van ruim 7500 koeien beoordeeld op de aanwezigheid en ernst van verschillende klauwaandoeningen. De klauwen verkeren veelal in een slechte conditie. Zo'n 80% van de koeien op een betonnen stalvloer toonde één of meerdere aandoeningen. De roostervloer met mestschuif scoort ten aanzien van infecties aan de klauw (o.a. ziekte van Mortellaro, stinkpoot) beter dan de traditionele roostervloer en de dichte vloer, die weinig verschilden qua klauwgezondheid. De mestschuif zorgt voor een drogere vloer, waardoor het aantal koeien met klauwinfecties afneemt. Koeien in een potstal hebben aanmerkelijk betere klauwen. Zowel het percentage koeien zonder enige klauwaandoening (~ 45%) als het aantal aandoeningen per koe zijn aanzienlijk lager in de potstal dan op de betonnen vloeren. Een mogelijk verklaring is dat in een potstal de klauwen veelal op een drogere ondergrond (strobed) staan, waardoor de infectiedruk lager is. Een ander voordeel is de dempende werking van het strobed. Uit de literatuur blijkt dat lopen en staan op beton leidt tot hogere piekbelastingen op de klauw, met als gevolg een grotere kans op klauwgebreken.

De twee voornaamste klauwaandoeningen in de Nederlandse melkveepopulatie zijn de ziekte van Mortellaro en stinkpoot. Beide infecties hebben een chronisch karakter. Stinkpoot tast het balweefsel aan en kan leiden tot diepe kloofvorming van het balhoorn. Mortellaro is een pijnlijke infectie van de huid ter hoogte van het balhoorn of in de tussenklauwspleet, en heeft een rode aardbei-achtige structuur. Met name de aanwezigheid van Mortellaro blijkt sterk te zijn toegenomen ten opzichte van 10 jaar geleden. In dit onderzoek had zo'n 30% van de koeien die gehuisvest zijn op een betonnen stalvloer aan één of beide achterpoten een zichtbare Mortellaro-laesie; in de potstal is dit percentage beduidend lager (4%).

Het onderzoek beschreven in **hoofdstuk 3 en 4** gaat over mogelijke risicofactoren van respectievelijk de ziekte van Mortellaro en stinkpoot. Hiervoor is gebruik gemaakt van de klauwbeoordelingen uit hoofdstuk 2. Op de bedrijven zijn gegevens verzameld over de huisvesting, management en voeding van de koeien. Ook zijn diergegevens vastgelegd zoals leeftijd en bepaalde productiekengetallen. Met behulp van logistische regressie zijn voor beide aandoeningen een aantal relevante risicofactoren geïdentificeerd. Zo komt naar voren dat 1e- en 2e-kalfskoeien, en koeien op bedrijven die een snelle opvoer van de krachtvoergift hanteren na afkalven, bijproducten voeren, en droge koeien al vòòr afkalven bij de lacterende koeien plaatsen, een verhoogd risico hebben op Mortellaro. Preventieve maatregelen zijn o.a. dag-en-nacht weidegang in de zomer, mestschuif op de roostervloer, comfortabele ligplaatsen in de stal (brede en lange ligboxen, strobed), opfok van jongvee in de melkveestal en 2x per jaar klauwbekapping.

Bij stinkpoot lopen oudere koeien het meeste risico. Evenals bij Mortellaro het geval bleek te zijn, leidt beperkte weidegang, een interval van klauwbekapping > 6 maanden, en droge koeien vòòr afkalven bij de melkkoeien plaatsen tot een verhoogd risico op stinkpoot. Het risico is te verkleinen door lange ligboxen en het gebruik van een mestschuif, opfok van jongvee in de melkveestal, en regelmatig voetbaden. Melkproductieniveau blijkt op beide aandoeningen geen invloed te hebben. Wel is het zo dat koeien tijdens de droogstand minder vatbaar zijn.

De bevindingen uit het epidemiologisch onderzoek roepen enkele belangrijke vragen op. Wat is de directe invloed van de slechte klauwgezondheid op het lopen en de activiteit van koeien? Waarom hebben koeien in een potstal minder aandoeningen dan op een betonnen vloer? Ook bestond tijdens het onderzoek de behoefte om een beter inzicht te krijgen in de ontwikkeling in de tijd van de ziekte van Mortellaro en stinkpoot op verschillende vloersystemen. Om al deze vragen te beantwoorden is een longitudinaal vervolgonderzoek uitgevoerd op 12 melkveebedrijven. Negen bedrijven zijn afkomstig uit het eerste onderzoek, waarvan drie bedrijven met een roostervloer, drie met een dichte betonvloer, en drie met een potstal. Aangezien ten tijde van de proefopzet een wet in de maak was die voorschreef dat alle koeien in ons land op termijn op een emissie-arme vloer gehouden zouden moeten worden, is besloten om het aantal bedrijven uit te breiden met 3 bedrijven met een sleufvloer. Op alle 12 bedrijven zijn 20 koeien at random geselecteerd (maar met een vergelijkbare verhouding in pariteit). Gedurende één jaar zijn de klauwen van de 240 dieren maandelijks beoordeeld op Mortellaro en stinkpoot. De longitudinale studie maakt het mogelijk om het verloop van verschillende ziektestadia van beide aandoeningen nauwkeurig vast te leggen. Dit in tegenstelling tot het eerste onderzoek, waarbij de klauwen van een koe slechts één keer zijn bekeken. Tegelijkertijd zijn een aantal fysieke klauweigenschappen gemeten en zijn afwijkingen in locomotie gescoord.

In **hoofdstuk 5** wordt de klauwvorm, hoorngroei en -slijtage, en de hardheid van het hoorn vergeleken op de verschillende vloeren. Vooraf was de hypothese dat een afwijkende klauwvorm, als gevolg van verstoorde groei en slijtage van het klauwhoorn, de oorzaak zou kunnen zijn voor de slechtere klauwgezondheid op de betonvloeren. Koeien in een potstal staan een groot gedeelte van de dag op stro en de verwachting was dat klauwen minder snel zouden groeien doordat de druk op de klauw in het strobed lager is dan op de betonnen vloer. De gemeten hoorngroei en slijtage tussen de potstal en de betonvloeren verschilden echter nauwelijks. De hoorngroei varieert tussen 5 en 5,5 mm per maand, terwijl de klauwen in dezelfde periode 2,5 tot 3 mm afslijten. Per saldo bedroeg de maandelijkse hoorngroei op de vier vloertypen 2 tot 2,5 mm. Ook zijn geen duidelijke verschillen gevonden in de klauwvorm (teenlengte, bal- en klauwhoogte, breedte, diagonaal) tussen de verschillende stalvloeren, met uitzondering van de klauwhoek. Koeien op een betonnen vloer hebben steilere klauwen dan koeien in een potstal (47 versus 43^0). Het hoorn van klauwen in de potstal was statistisch niet-significant harder dan op betonnen vloeren.

Stinkpoot ontwikkelt zich lineair in de tijd, ongeacht het vloertype. De ernst van stinkpoot is vastgelegd aan de hand van een score van 0 (= afwezig) tot 4 (= ernstig); twee weken na bekappen vond de eerste beoordeling plaats. Op alle vloersystemen vindt gaandeweg de observatieperiode een zelfde verschuiving plaats van score 0 en 1 naar score 2, 3 en 4. Ter illustratie: op 6 weken na bekappen heeft 15% van de klauwen score 0 en ruim 45% heeft score 1. Drie maanden later (week 18) heeft minder dan 20% score 1 of lager, terwijl bijna 80% score 2 of score 3 heeft. Zodra klauwen bekapt zijn, herstelt de kloofvorming in het balgebied en krijgen de meeste klauwen de score 0 en 1.

Evenals in het eerste dwarsdoorsnede-onderzoek, was de stalvloer in dit longitudinale onderzoek een belangrijke risicofactor voor Mortellaro. In de potstal hebben opmerkelijk weinig koeien deze aandoening. Van de betonvloeren scoort de roostervloer significant beter dan de dichte beton- en sleufvloer. Mortellaro kent geen duidelijk lineair verloop. Van de koeien met een beginnende Mortellaro-infectie (M1) is na vijf maanden 50% herstellende/inactief (M3, M4) of genezen (M5), terwijl zo'n 35% overgaat in een ernstige laesie (M2). Koeien met M2 hebben een slechte prognose. Na vijf maanden zit slechts 15% in stadium M3, M4, of M5. Zo'n 65% blijft onveranderd, terwijl 20% teruggaat naar M1.

In **hoofdstuk 6** is op de verschillende vloertypen gekeken naar het effect van Mortellaro- en stinkpootinfectie op de locomotie van koeien. Belangrijke aspecten bij deze beoordeling zijn de mate van onbalans in de beweging en plaatsing van de achterpoten, en de kromming van de rug. De locomotie is grofweg in te delen in de categorieën normaal, gevoelig en gestoord/kreupel. Koeien in een potstal lopen veruit het beste. In ruim 80% van de gevallen lopen ze normaal, gemiddeld 17% loopt gevoelig en minder dan 1% is kreupel. Koeien die worden gehuisvest op een betonnen vloer lopen aanzienlijk slechter. Een kwart van deze koeien loopt gevoelig, terwijl bijna 30% een gestoorde locomotie en dus enige kreupelheid laat zien; slecht 45% van de dieren loopt normaal en onbelemmerd. Een verklaring voor de gevonden verschillen in locomotie is enerzijds de zachtere, dempende vloer in de potstal. Het strobed zorgt voor minder drukbelasting op de klauwen waardoor koeien zich makkelijker kunnen voortbewegen. Anderzijds geldt dat de klauwgezondheid in de potstal aanmerkelijk beter is, met name qua Mortellaro infectie. Juist Mortellaro zorgt voor een duidelijke verslechtering in locomotie. In het onderzoek laat ruim een derde van de koeien met Mortellaro een gestoorde locomotie zien, terwijl 20% gevoelig loopt. Bij koeien zonder Mortellaro zijn de percentages 14 en 30. Ook stinkpoot heeft in geval van diepe kloofvorming nadelige effecten voor de locomotie.

Van de 12 bedrijven in de longitudinale studie is op één bedrijf per vloertype aanvullend gedragsonderzoek uitgevoerd. De resultaten in **hoofdstuk 7** laten zien dat zowel gestoorde locomotie als de ziekte van Mortellaro leiden tot een verandering in activiteitsbesteding per 24 uur. Kreupelheid leidt tot een verandering in liggedrag. Kreupele dieren gaan minder vaak liggen in de boxen, maar per keer liggen ze beduidend langer dan hun niet-kreupele soortgenoten. Tevens staan koeien met een ernstige locomotiestoornis korter te vreten aan het voerhek, en arriveren ze later in de melkstal. Kreupele koeien lijken het gedrang in de wachtruimte te vermijden. Ook Mortellaro beïnvloedt het liggedrag. Dieren met ernstige Mortellaro liggen per dag minder lang in de ligboxen. De kortere ligtijd wordt gecompenseerd door langer staan in de box. Tot slot is het gedrag vergeleken tussen niet-kreupele dieren in een ligboxenstal en potstal. Koeien in een potstal liggen gemiddeld 2 uur langer per dag. Die tijd wordt door hun soortgenoten in de ligboxenstal doorgebracht met staan/lopen op de betonnen vloer.

Dit proefschrift onderstreept de grote omvang van het probleem van klauwaandoeningen en gestoorde locomotie in de melkveehouderij. Niet alleen bestaat een hoog niveau van klinische verschijnselen, maar ook zijn duidelijke gevolgen voor het gedrag waargenomen. De resultaten tonen verder aan dat via gerichte maatregelen op het gebied van huisvesting en management de situatie op een bedrijf kan worden verbeterd. De toepassing van zachte, dempende stalvloeren kan een structurele bijdrage leveren aan de oplossing van het probleem.

Curriculum Vitae

Joan Somers werd op 12 oktober 1974 geboren te Vorstenbosch. In 1993 behaalde hij het Gymnasium-diploma aan het Zwijssen College in Veghel. In september van dat jaar begon hij de studie Zoötechniek aan de Landbouwuniversiteit Wageningen. In augustus 1998 behaalde hij zijn bul met afstudeervakken Gezondheidsleer en Reproductie, Agrarische Bedrijfseconomie en Milieutechnologie en een stage aan de University of Minnesota.

Daarna werkte hij zes maanden als onderzoeker economie en bedrijfsvoering bij het Praktijkonderzoek Varkenshouderij in Rosmalen. In maart 1999 maakte hij de overstap van varkens naar koeien. Hij werd aangesteld als onderzoeker in opleiding bij de Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO). Aanvankelijk vanuit de Faculteit Diergeneeskunde in Utrecht en later bij het IMAG in Wageningen, werkte hij aan het in dit proefschrift beschreven onderzoek naar klauwaandoeningen en gestoorde locomotie bij melkkoeien.

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