

Aus dem Institut für Tierhygiene, Tierschutz und Nutztierethologie
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**Welfare of Dairy Cows:
Lameness in Cattle – A Literature Review**

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Meiner Familie

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1. Introduction

Globally, livestock production is growing rapidly as a result of increasing demand for animal products. This holds also true for the dairy industry, the centre of which are dairy cows. Their well being, health and welfare are important for successful production and economic success. Lameness is one of the most serious welfare problems for the dairy cow, and yet it is one of the least well-managed health problems of dairy cattle. Foot and leg disorders tend to increase along with increased production and more confined management systems. Many factors influence lameness in cattle, as there are housing, flooring, daily exercise, hygiene, nutrition, management and stockmanship, veterinary care and claw trimming, as well as genetics.

These factors can be considered general scientific knowledge, yet there are only a few consolidated reports which comprise the important facts and underlying mechanisms, and which deliver a risk assessment scheme that identifies the most critical points and that helps to deduce clear recommendations for practical on-farm application. Therefore, it seems useful to review the literature published so far in order to analyse the most important factors and practices influencing the occurrence of lameness. In addition, it seems to be essential to try and develop a practical first step risk assessment of lameness in dairy cows. This is meant to demonstrate the severity of lameness and its degree of influence on the welfare of dairy cows, and it is supposed to serve as a scientific basis for the future development of systems that determine hazards and aim at controlling critical points in dairy cow production. Thoughts on future research subjects and practical implementations as well as recommendations on how to prevent lameness and suffering for dairy cattle in the future will be added.

2. Dairy Cattle Industry and Economic Impact of Disease

Lameness in cattle is considered to be an important health problem in dairy herds and one of the greatest welfare problems of dairy cows (BROOM 1992). It is a widely held view that increased productivity and intensification of dairy cow management is necessarily associated with increased occurrence of lameness and reduced cattle welfare. Lameness, on the other hand, has a negative impact on feed intake, milk production, reproduction and health in general, and therefore can result in more or less severe economic losses.

2.1. Dairy Cattle Industry

From 1980 until 1998 the world cattle population showed an increase from 1.218.075 in 1980 up to 1.314.557 in 1998 (BAUMGARTNER 2002). Globally, livestock production is growing rapidly as a result of increasing demand for animal products. Up to the year 2030, cattle numbers are predicted to increase by around 400 million (JUTZI 2002). The intensity of stocking has increased rapidly over the last few decades as well (JARVIS 2002), which means that more cattle are kept on fewer farms.

Table 1: EEC dairy structure 1983 (pre milk structures).

	Cows (‘000)	Herds (‘000)	Average herd size	Yield (l/cow)	Total pro- duction (‘000 t)
Germany	5451	363	15,3	4650	26007
France	6506	367	19,8	3950	33337
Italy	3120	424	7,3	3540	11030
Netherlands	2333	58	40,8	5330	12550
Belgium	946	45	21,7	3930	4145
Luxembourg	70	2	29,7	4274	320
UK	3257	54	58,2	4906	17680
Irish Republic	1528	77	19,9	3910	6480
Denmark	913	35	28,2	5585	5205
Greece	219	77	3,1	3200	770
Portugal	369	115	3,2	3021	1115
Spain	1885	-	-	3382	6375

Source: EEC Dairy Facts and Figures, 1986 (MMB, Thames Ditton).

Dairy farming in Europe in the 1980ies and 1990ies was a diverse industry. There were large herds of high-yielding cows in the Netherlands, Denmark and the UK, and low-yielding herds in Greece, Portugal, Spain and Italy (POOLE and ANDREWS 1992), as it is shown in table 1.

The European situation until 1990 has been mirrored in the structure of dairy farming in England and Wales over this time: fewer producers, similar numbers of cows in larger herds, and a higher yield per cow (see table 2) (POOLE and ANDREWS 1992). Small herds were virtually eliminated: in 1990, there were just over 5% herds of less than 30 cows, whereas in 1972 there were 20% (POOLE and ANDREWS 1992).

Table 2: England and Wales dairy structure 1965-1990.

	Producers (‘000)	Cows (millions)	Herd size	Yield (l/cow)
1965	100,5	2,65	26	3545
1970	80,3	2,71	33	3755
1975	60,3	2,70	46	4070
1980	43,4	2,67	58	4715
1983	39,7	2,74	67	5085
1984	39,3	2,70	67	4950
1986	37,1	2,57	68	4930
1988	33,7	2,38	69	4870
1990	31,5	2,33	70	5020

Source: UK Dairy Facts and Figures, 1990.

Each country had expanded herd size and yield per cow to increase the total production. The number of dairy producers had been generally declining, whereas the total cow population had not increased in the same extent (POOLE and ANDREWS 1992).

During the recent years, dairy cattle numbers have decreased, in Germany as well as in Europe (see table 3).

Table 3: Number of dairy cows (in thousands) in the EU – May/June 2002.

Country	Number of dairy cows	+/- (compared to year before)
Belgium	577.3	-3.3
Denmark	611.0	-1.9
Germany	4430.5	-2.6
Greece	-	-
Spain	1167.4	+5.9
France	4038.2	-2.8
Ireland	1257.2	-1.7
Italy	2199.0	+2.1
Luxembourg	41.9	-2.1
Netherlands	1523.0	-4.9
Austria	600.1	-2.7
Portugal	-	-
Finland	347.8	-2.0
Sweden	417.1	-0.3
Great Britain	2224.8	-1.2

Source: Vet Report, Tierärztliche Umschau 2003a.

Germany counted 4,03 million dairy cattle in November 2006, this being 3,2% less cattle than in November 2005 (see table 4). It was already in 2005 that a decrease above average in dairy cattle numbers was registered; there were 2.8% fewer dairy cattle compared to one year before. By the end of 2000, Germany had 534 000 dairy cows less than during the years before, and cattle herds became smaller every year (WOHLFAHRT 2007a).

Table 4: Dairy cattle herds in Germany (counted in millions; stock counting performed in November and December; estimations for 2006) from 2001 to 2006.

Source: www.zmp.de/presse/agrarwoche/marktanalyse/ma07.pdf (08/08/2007)

Similar to Germany, numbers of dairy cows have decreased in the EU as well; this is true for every EU-country except for Poland. Decrease was highest in Spain, Hungary and Slovenia; in Germany, Belgium, The Netherlands and Portugal decrease was above average. Denmark, Great Britain, Ireland and France showed less decrease. 22,57 million dairy cows were counted in the EU in May 2006; this is 2.2% fewer dairy cattle than in 2005. The number of dairy cattle herds was reduced in nearly all EU-countries, except for Poland that increased herd numbers by 0.8% (WOHLFAHRT 2007b).

Table 5: Dairy cattle herds in EU-countries 2005 and 2006 (counted in thousands; stock counting performed in May and June; ¹⁾ taking December-counts of the previous year into account; ²⁾ taking December-counts of the previous year partly into account).

EU-MILCHKUHBESTÄNDE			ZMP
Mai/ Juni, 1.000 St.	2005	2006	± %
Belgien	549	529	- 3,5
Dänemark	558	555	- 0,5
Deutschland	4.236	4.117	- 2,8
Spanien	1.074	982	- 8,6
Frankreich	3.734	3.666	- 1,8
Irland ¹⁾	1.122	1.101	- 1,8
Italien	1.848	1.824	- 1,3
Niederlande	1.511	1.463	- 3,2
Österreich	541	535	- 1,0
Großbritannien	2.071	2.046	- 1,2
EU-15 ²⁾	18.487	18.028	- 2,5
Tschechien	439	426	- 2,9
Litauen ¹⁾	434	417	- 4,0
Polen	2.752	2.775	+ 0,8
EU-25 ²⁾	23.088	22.571	- 2,2
Bulgarien ¹⁾	368	348	- 5,5
Rumänien ¹⁾	1.566	1.625	+ 3,8

1) Dezember-Zählung des jeweiligen Vorjahres. 2) Teilweise unter Berücksichtigung von Werten der Dezember-Zählung des jeweiligen Vorjahres. Quelle: ZMP, EUROSTAT, nationale Statistiken

Source: www.zmp.de/presse/agrarwoche/marktanalyse/ma07.pdf (08/08/2007)

According to statistical data, every second farm animal (except poultry, fish and bees) in Europe is a cow. There were 59 million cattle among 118 million farm animals in the total (VET REPORT 2003a). Producing cattle in Europe has undergone a certain rise: 27.4 million animals were produced in 2002; this makes an increase of 4.3 percent compared with 2001. However, recent tendencies in cattle stocking show a slight decrease. While in 2002 there

were only 81 million cattle in the EU, there had been 65 % more animals in 1998 (VET REPORT 2003b).

Table 6: Livestocking in 2001 of the countries having joined the EU.

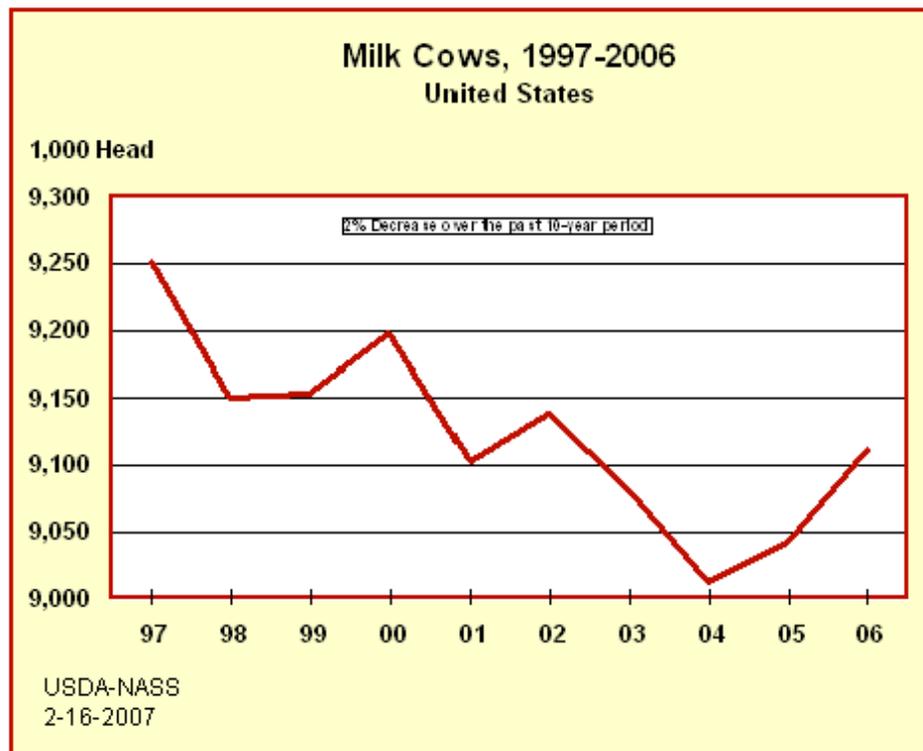
Country	Number of dairy cows
Bulgaria	367.2
Cyprus	24.4
Czech Republic	506.0
Estonia	129.3
Hungary	345.0
Latvia	209.1
Lithuania	441.8
Malta	no data available for 2001
Poland	2526.7
Romania	no data available for 2001
Slovakia	no data available for 2001
Slovenia	135.8

Source: Vet Report, Tieraerztliche Umschau 2003c.

In addition to the data mentioned above, it must not be forgotten that the EU has gained new members belonging to the eastern regions of Europe. About 94.2 million cattle from these eastern countries will add to the rest of Europe's cattle. Among these new member states, it is Poland that brings in the most cows: 5.5 million cattle, among them 2.5 million dairy cows (VET REPORT 2003c); Romania and Bulgaria add another 2 million dairy cows to the overall European numbers (WOHLFAHRT 2007a).

In the USA cattle numbers continued to lessen since the mid-1990ies: in 2003 there were only 96.1 million cattle counted. It was in 1990 when numbers had been this low for the last time (VET REPORT 2003d). In contrast to this there had been 96.7 million cattle in 2002 and 97.3 million cattle in 2001. The number of dairy cows decreased as well by 130 000 animals, thus making a total of 42.1 million dairy cows in 2003. Since 1952, this has been the lowest number ever (VET REPORT 2003d).

Table 7: Number of milk cows in the United States 1997-2006.



Source: www.nass.usda.gov/Charts_and_Maps/Milk_Production_and_Milk_Cows/milkcows.asp (08.08.2007)

Between 1997 and 2006 there has been a 2%-decrease in dairy cow numbers. Since 2004, dairy cow numbers are rising again, from about 9 000 000 cows in 2004 up to 9 120 000 cows in 2006 (www.nass.usda.gov/Charts_and_Maps/Milk_Production_and_Milk_Cows/milkcows.asp (08.08.2007)).

2.2. Frequency of Bovine Lameness

In 1997, the Farm Animal Welfare Council (FAWC) completed a report commissioned by the former Ministry of Agriculture, Fisheries and Food on a wide range of subjects concerning the welfare of dairy cows. The council put a focus on lameness in dairy cows, which it found to be at an “unacceptably high level” (FAWC 1997). It stated that “lameness is an extremely painful condition and steps must be taken, as a matter of urgency, to reduce the incidence” (FAWC 1997). An average farm annual incidence rate of 55% is estimated, with a

prevalence rate of 20%. The council announced a review of the situation to be brought out in 2002 (O'CALLAGHAN 2002), but this did not happen until today.

Lameness, for reasons of prevalence and severity, is considered to be the single most severe welfare problem for dairy cows by WEBSTER (2002). The point which is most worrying in this context is the fact that approximately one third of cows experience lameness annually (MUELLING and LISCHER 2002); data from the UK mention 20-22 % per annum respectively (WARD 2001; WEBSTER 2002).

Lameness is currently ranked as the third most important disease affecting the UK dairy industry (O'CALLAGHAN 2002). A survey made of 37 dairy farms in the UK by CLARKSON and DOWNHAM (1996) showed that the mean annual incidence of lameness was 54.6 new cases per 100 cows (with a range from 10.7 to 170.1), and the mean values during summer and winter were 22.9 and 31.7 respectively. WARD (2001) mentions 55 new cases for every 100 cows per year; OFFER et al. (2000) reported a mean incidence of lameness of 51.5 cases per 100 cows during a six month period of winter housing, whereas GROEHN et al. (1992) reported that 146 out of the 3610 cows monitored became lame; this makes an overall annual incidence rate of only 4,4%.

CLARKSON and DOWNHAM (1996) found the mean annual prevalence to be 20.6% (ranging from 2.0 to 53.9%); the mean prevalence during summer and winter were 18.6 and 25.0% respectively. GALINDO et al. (2000) report a lameness prevalence of 42% during winter housing, and ESPEJO et al. (2006) mention a mean prevalence of clinical lameness of 24.6%.

As statistics show, more than 90% of lameness in dairy cattle involves the foot, and of that, more than 90% involves the rear feet, with the majority of disorders affecting the outside claw (VERMUNT and SMART 1994; SHEARER and VAN AMSTEL 2002). A high proportion of cows become lame within the first two months of their first lactation (LEACH et al. 1998; WEBSTER 2001a) and regularly relapse (OFFER et al. 2000). The fact that 50% of the animals will experience the chronic pain of lameness in any one lactation (WEBSTER 2002) can thus be considered alarming.

2.3. Economic Impact of Disease

An animal suffering from any kind of pain does not produce in an optimal fashion. Speaking in economic terms, lameness causes decreased milk yield, reduced reproductive performance, high culling rates and increased cost of veterinary intervention (HASSALL 1993; VERMUNT and SMART 1994; COLLICK 1994; BERGSTEN 2001; MUELLING and LISCHER 2002).

The pressure of efficiency improvement is one of the major reasons for changes in management, which can influence the incidence and prevalence of a number of diseases in dairy cattle (LOGUE 1997). The veterinary profession has recognized the poor state of information on economic impacts of food animal diseases for a long time; it was first mentioned by the National Academy of Sciences in 1966. The need for this kind of information is given because it can be used to evaluate farm productivity and profitability and to design animal health programs (MILLER and DORN 1990). As the developed nations have gained control over the more devastating contagious diseases, diseases related to herd management have now become more evident (MILLER and DORN 1990).

Lameness in dairy cattle is currently ranked as the third most important disease affecting the UK dairy industry (after reduced fertility and mastitis) and continues to be one of the largest financial drains on the UK dairy industry (LOGUE 1997; OLSEN 1997; O'CALLAGHAN 2002). In the UK, losses as a result of lameness in cattle are estimated to be £30 per lame cow (WHITAKER et al. 1983); financial annual losses from lameness may amount to £1000 per 100 cows, and the loss to the dairy industry of the UK could be £15 million each year (GREENOUGH 1996). WARD (1999) reports the costs caused by lameness to be £43 million to 65 million, the costs of treatment £6 million to 51 million, and the costs of prevention £3 million to 5 million (WARD 1999). The National Animal Health Monitoring System (NAHMS), designed by the U.S. Department of Agriculture, estimated costs of disease to be \$172,40 per cow and year. Among these specific diseases, lameness accounted for 5% (following mastitis (26%) and infertility (13%)). Considering the total preventive costs of \$20,88 per cow and year, drugs accounted for 52%, veterinary services for 33%, and producer labour for 15%. The largest component of preventive expenditure for lameness was foot trimming (MILLER and DORN 1990). In the Netherlands, lameness in adult dairy cattle is estimated to come in third place (after mastitis and reproductive failures) ranking diseases on

an economic scale; in Denmark, there is a loss of 38 Dutch guilders per lame cow and in Sweden net income per year increased with the increasing lifetime of the individual cow until at least the sixth lactation. (FRANKENA et al. 1992).

The costs of lameness depend on the type of lameness, its duration, and the age and stage of lactation of the cow. The direct costs to the dairyman comprise costs for treatment and extra labour, reduced milk production, loss of body condition, a prolonged calving interval as a consequence of sub-optimal or even no oestrous expression, increased risk for teat lesions, and a higher culling risk together with reduced slaughter value (NOORDHUIZEN et al. 1996). Sole ulcers appearing in early or mid-lactation cost an average of £72 (direct costs) respectively £246 including the costs of reduced fertility and performance (KOSSAIBATI and ESSLEMONT 1999), GREENOUGH (1996) talks about £130-180 for a single case of sole ulcer; BERGSTEN (2001) mentions \$650 for a single sole ulcer. Lameness due to digital dermatitis is estimated to cost £59 per case; one case of interdigital dermatitis might cost £55-100 (GREENOUGH 1996). On average, the costs of a case of lameness are calculated to be approximately £140 (KOSSAIBATI and ESSLEMONT 1999), if the lameness is treated promptly (O'CALLAGHAN 2002); AMSTUTZ (1985) estimated the average annual loss per lame cow to be approximately \$200, KOSSAIBATI and ESSLEMONT (1995) calculated the total cost of a case of lameness to be at £250.

The causal relationship between disease and reproductive performance shows itself in loss of weight and body condition, and reduced milk yield and fertility (MCDERMOTT et al. 1994; similarly COLLICK et al. 1989; GROEHN et al. 1992; BERGSTEN 2001; WARNICK et al. 2001; HERNANDEZ et al. 2002). GROEHN et al. (1992) found that prolonged calving intervals, secondary mastitis and reduced milk quality cause additional losses due to lameness, which are economically important as well. MOSER and DIVERS' herd-based case study (1987) reported a marked decrease in milk production, progressing to agalactia within about 30 days after the onset of lameness in improperly fed cows. WHITAKER et al. (1983) found that an average of 20% of the total lactation was lost from each affected cow. VERMUNT and SMART (1994), too, found that 20% of the total lactation was lost from each affected cow. They state that costs for treating a lame cow are due to treatment, milk withdrawal and extra labour, decreased milk production, reproductive efficiency and bodyweight, and premature culling and replacement costs (VERMUNT and SMART 1994). HERNAN-

DEZ et al. (2002) reported a yield decrease of approximately 500 kg per lame cow. GREEN et al. (2002) found that lame cows not only undergo a decrease in milk yield, but that the yield reduction started four months prior to the onset of lameness and continued until five months after treatment; even a severely lame cow can produce about 30 litres of milk per day. (GREEN et al. 2002; similarly BLOWEY 1998). Depending on the degree of lameness, milk yield decreases accordingly: the lamer a cow is, the lower the milk yield will be (HERNANDEZ et al. 2005).

Lameness appears to be a significant risk factor for culling throughout lactation. Cows that were treated for foot and leg problems at the beginning of the lactation had a risk of being culled that was six times higher than with sound cows. Cows treated for foot and leg problems during the second month of their lactation even had a twelve times higher risk of being culled during that month than did healthy cows (RAJALA-SCHULTZ and GROEHN 1999). Chronic lameness is likely to reduce milk yield and fertility and predispose to early culling (WEBSTER 2002). Culling rates increase, and costs for herd replacement increase as well (OLSEN 1997; BERGSTEN 2001; O'CALLAGHAN 2002). In The Netherlands, for example, the average culling rate ranges from 16 to 33% per year. In about 68% of the cases, culling is forced due to disease, 60% of which are made up by lameness and reproductive disorders. This means that on average 25 heifers per 100 cows are needed for herd replacement; one heifer costs about \$850 on total, which makes a total cost of \$21.250 per year (NOORDHUIZEN et al. 1984). COLLICK et al. (1989) found that 16% of all lame cows were culled; KOSSAIBATI and ESSLEMONT (1995) showed that 5.6% of culls in 50 dairy herds in England in 1990-1992 were caused by lameness. A US study (ETHERINGTON et al. 1996) reported that lameness accounted for 10% of culls, while a French study found only 3% (SEEGERS et al. 1998). In all cases, however, reproductive problems were major causes of culling, with lameness contributing indirectly (WARD 2001). Lameness in a herd means increased labour requirement, increased treatment costs, reduced milk production, reduced fertility, and involuntary culling and decreased slaughter value for the farmer (ALBAN et al. 1996; similarly VERMUNT and SMART 1994; GREENOUGH 1996; Ward 1999).

3. Dairy Cow Health and Welfare

The welfare and health of dairy cows can be influenced by a variety of physical and mental disorders. In dairy cows, disorders of reproduction, mastitis and lameness are the most frequent reasons for veterinary treatment and culling, with lameness having played an increasing role since about 30 years (LOGUE 1997; O'CALLAGHAN 2002). Lameness is seen as the greatest welfare problem of housed dairy cows (BROOM 1992). Besides its negative impact on feed intake, milk production, reproduction and health in general, lameness adversely affects the welfare of the diseased cows as it is often long lasting, and associated with pain, discomfort and a loss of fitness (ALBAN 1995; WEBSTER 1997). By housing and managing animals man has taken on the responsibility of the animals' well-being (ČERMÁK 1994). Besides challenging dairy cow welfare, lameness results in changes of cow behaviour and decreased cow comfort.

3.1. The Concept of Welfare

It is a widely held view that increased productivity and intensification of dairy cow management is necessarily associated with reduced welfare (BERGSTEN 2001; SHEARER and VAN AMSTEL 2002). The term 'welfare' is not consistently defined, and is influenced by the human perception of 'welfare' and ethical questions (SANDØE et al. 2003). Several authors (BROOM 1986; WEBSTER 1994) have attempted to find an appropriate and consistent definition of the term 'welfare', taking cow behaviour and their own rather subjective view of the matter as a basis, but had to face the limits of their own explanations to some extent. It becomes obvious that 'welfare' can hardly free itself of the subjectivity of the person talking about it. Thus, a consistent and objective explanation or even definition will still have to be subject to future research. With this voluntary renouncement of knowledge by the scientific community caused by a shortage of selectivity in defining, those who attempt to explain the term 'welfare' mostly use cow behaviour as basis of their explanations.

Attempts to explain or even define 'welfare' are always influenced by some kind of human concern. MCINERNEY (1997) published some thoughts on the complicated nature of any definition of 'animal welfare'. He believes that the concern humans show for animal welfare is based on their own perceptions of how animals are affected by the conditions under

which they are kept. Therefore, he prefers to term the issue ‘perceived welfare’ to avoid any suggestion that animal welfare has been or can be objectively assessed (MCINERNEY 1997). He says that welfare can be viewed from the *animal’s* point of view, but can also be viewed by placing *people* into the centre of the problem. MCINERNEY (1997) thinks that it is actually the people-centred (anthropogenic) view that dominates our perception of animal welfare, as animals (and especially livestock animals) are managed by people who impose their preferences over them. He states that defining standards for animal welfare is so difficult because every person has an individual notion of what he or she believes to be the optimum of welfare standards.

WEBSTER (1994), too, believes the problem in defining ‘welfare’ lies in the use of behaviour observations (i.e. what the animals *do*) in order to assess animal welfare, whereas an animal’s assessment of welfare would be based on its perception of the quality of life within a spectrum ranging from suffering to pleasure (i.e. how they *feel*). DUNCAN and POOLE (1990) published similar ideas a few years earlier; they believe that although physical health and freedom from injury are important, it is how the animal ‘feels’ about its bodily state, how it ‘perceives’ its environment and how ‘aware’ it is of these feelings and perceptions that are the crucial notions of ‘welfare’. According to this, an animal’s feelings about itself and its environment are of great importance. Feelings, however, cannot be studied directly in animals, so researchers are forced to stay with their concept of observing behaviour (BROOM 1986; NICOL 1994; WEBSTER 1997; BROOM 2006), using it as a means of detecting feelings.

It has long been recognized that animal welfare is more than just the freedom of disease. In 1965, the Brambell Committee expressed their concept of welfare in the so called ‘Five Freedoms’: they proposed that all farm animals should at least have the freedom to stand up, lie down, turn around, groom themselves and stretch their limbs (WEBSTER 1997). WEBSTER (1997) finds these standards to be “a very inadequate definition of freedom” (WEBSTER 1997) since it concentrates almost exclusively on one aspect of behaviour (comfort seeking) to the exclusion of everything else that might contribute to good welfare, like good food, health or security. He believes that by this definition there should be no welfare problems for the dairy cow (WEBSTER 1997). WEBSTER (1997) proposes a more comprehensive ‘Five Freedoms’ for first analysis of all the factors likely to influence the welfare of farm

animals: freedom from thirst, hunger and malnutrition; freedom of discomfort; freedom of pain, injury and disease; freedom to express normal behaviour; and freedom from fear and distress (WEBSTER 1997; similarly LOGUE 1997).

WEBSTER (1995) believes that the animal should be able to resolve potential problems raised by the limitations of the above-mentioned freedoms by conscious action. This is not at all encompassing, as there are cases in which the cow simply cannot do this and stockmanship and veterinary treatment are required (LOGUE 1997). In fact, the welfare of an animal cannot simply be attributed to the way and capability of an animal to cope with its environment. Coping finds its limits whenever conditions surrounding the cow (like housing, nutrition and veterinary care) have an adverse effect on cow health, but cannot actively be altered by the cow and her behaviour, but could only be changed by the person responsible for the animals. WEBSTER's later explanation (2002) of the "welfare of any sentient animal" poses similar problems. He states that it may be defined "by its capacity to sustain fitness and avoid suffering" (WEBSTER 2002). The question comes up as to which degree an animal kept in captivity can actively sustain fitness and avoid suffering and whether this can really be considered a question of capacity only.

The notion of some sort of control over the environment can already be found in Broom's definition of 'welfare' in 1986: he believes the welfare of an individual to be "its attempt to cope with its environment" (BROOM 1986). Broom states that individuals start to use various methods – like regulatory behaviour, stereotypes or overproduction of certain physiological hormones and transmitters – in trying to counteract adverse effects as soon as conditions become difficult. He claims that two aspects – the lack of success and ways of trying to cope with it – can be measured (BROOM 1992), and that lame cows do not cope as successfully with their environment as do non-lame cows (GALINDO and BROOM 2002; BROOM 2006). The question is what the term 'coping' does imply in this context, it needs some benchmarks which describe the extent of coping of the cow and which tell whether the stresses she is under are acceptable or not (LOGUE 1997).

WIERENGA and BLOKHUIS (1997), too, believe that the welfare of an animal is good as long as the individual is coping successfully with its environment and is free of pathologies and pain. In the course of evolution each animal species has been adapted to a specific environment in which it is able to survive and to reproduce. Accordingly, welfare problems can

then be measured in terms of the effects of lack of behavioural and physiological control and the biological costs of the coping response, e.g. immunosuppression and the occurrence of diseases.

WEBSTER (2002) states that lameness constitutes the most serious systematic insult to dairy cow welfare since it imposes suffering on a high proportion of animals within the first few weeks of their productive life. He believes that the magnitude of the welfare problems for a population of farm animals is defined by the incidence, duration and severity of the condition. Environmental factors as well as the commitment of the farmer and the veterinarian are important in this context. The time lag from original insult to examination and treatment permits treatable lameness conditions to progress to the point of irreparable damage. By improving these conditions the cattle industry could gain tremendously in animal welfare by providing prompt relief to suffering animals. Moreover, less lameness in cattle could save the dairy industry millions of dollars (SHEARER and VAN AMSTEL 2002). WEBSTER (2001b) agrees that it is not the farmer alone who can ensure good welfare. He considers that improvements to farm animal welfare can only come about within the context of the forces that drive the free market. He believes that welfare-based quality assurance schemes with quality control ensured by independent audit could be used to reach this goal.

Animal welfare is not only ambivalent in terms of the angle from which to view it (man's point of view or the animal's point of view), but must be considered ambivalent with respect to economic desires versus animal well-being, too. In 1992, Broom thought about whether improved welfare could lead to improved production; he thinks that if the welfare of a dairy cow is improved there is often a greater milk yield and an increase in survival chances, which in turn would lead to economic advantages for the farmer. MCINERNEY (1997), too, talks about economic impacts (i.e. costs) when procedures are done in order to improve animal welfare. "What society is now looking for is [...] the appropriate balance between livestock productivity and economic efficiency on the one hand, and our perception of the animals' interests on the other" (MCINERNEY 1997). The author states that setting welfare standards is always an economic choice, and that it might be difficult to improve welfare standards within the currently existing husbandry systems. He believes that if animal science could devise new production techniques, it could create production systems that could offer both higher productivity and higher animal welfare (MCINERNEY 1997).

Animals possess a variety of physiological and behavioural mechanisms to cope with demands from their environment. When these coping responses are not successful or when they are thwarted, specific stress symptoms like disturbed behaviour, organ damage, increased susceptibility for diseases, expressions of fear and pain may occur (WIERENGA and BLOKHUIS 1997; BROOM 2006). Some authors have tried to collect these symptoms in order to devise useful welfare assessment systems. FREGONESI and LEAVER (2001) carried out a study on dairy cattle responses to the two most common loose-housing systems, straw yards and cubicles. EGAN et al. (2001) surveyed housing and calving factors relevant to animal welfare. WHAY et al. (2002) and WHAY et al. (2003a) studied 53 UK farms and used a welfare assessment relying on direct observation of the animals and animal-based correlates of welfare (such as milk yield and conception rate to first service and records of treatment). WHAY et al. (2003b) carried out a study on animal-based measures for the assessment of the welfare state of dairy cattle, pigs and laying hens; this study was meant as a basis for the development of welfare assessment protocols. WINCKLER et al. (2003), too, selected management and housing parameters for on-farm welfare assessment protocols. MENCH (2003) discussed possible aspects of assessing animal welfare at farm level in the USA. ROUSING's (2003) 'Protocol of Welfare Indicators' aims at developing and evaluating animal welfare indicators and evaluating a welfare assessment system in commercial animal production. BOWELL et al. (2003) studied the effects of building design and management system on dairy cow welfare, and HOERNING (2003) tried to integrate different parameters of cattle housing into an animal welfare assessment scheme. HASKELL et al. (2003) investigated the effect of management and housing type on behaviour and welfare of cattle in an on-farm assessment.

The aetiology of most herd health and welfare problems is complex, and attempts by scientists to attribute them to single causes should be treated cautiously (WEBSTER 1997). Presently, there are no standards for animal welfare risk assessment (BROOM 2006). The way research on the subjects of animal welfare and welfare assessment has been conducted has shown to have some limitations. The studies are using different methods and have the tendency to focus on single factors contributing to welfare, like housing, flooring or group size. But when it comes to assessing the welfare of the animals on a specific farm, the single welfare factors cannot simply be added up. Management and stockmanship are particularly

variable factors (SANDØE et al. 2003). STULL et al. (2005) showed that the selection of a welfare assessment program for assessing the welfare status on a specific farm is important as it determines the outcome of the assessment.

It was in 1986 already that Broom claimed that each individual has its own strategy of coping with difficult situations, and poor welfare can be expressed by a large number of indicators. Therefore, welfare assessment systems should contain a wide range of welfare indicators (BROOM 1986), and require evaluation on a scientific basis (BROOM 2006). In the development and application of measures of animal welfare, researchers should define some aspects in order to explain what they are talking about: they should define the conception of animal welfare they apply, the items measured, the focus and a cut-off between 'acceptable' and 'not acceptable' (SANDØE et al. 2003). It is important that science keeps providing answers to the welfare questions raised by society, but it is equally important that scientists reflect on the ethical assumptions behind their research and make these assumptions transparent. Scientists have focussed differently when assessing animal welfare – and are still doing so – but hardly any of them explain the underlying ethical assumptions and categories of measurement explicitly, so that those who want to use the results would be provided with a clear understanding of what is being talked about (SANDØE et al. 2003). This discussion about welfare and its implications shows the need for a generally accepted and scientifically useful definition of the term 'welfare', for transparent explanation of ethical assumptions, and for objective methods to assess the welfare of livestock in different environments.

3.2. Cow Comfort and Behavioural Alterations

The idea of dairy cow comfort is inherent in the notion of cow welfare. Cow comfort implies that a cow feels comfortable about its surroundings, and can easily meet its need for 'feeling' good and safe by using given stall features. The term cow comfort is not consistently defined, and is influenced by the human perception of 'comfort' as well. COOK et al. (2005) tried to assess cow comfort by monitoring certain Cow Comfort Indices (CCI's, for example Stall Standing Index, Stall Perching Index and Stall Use Index), but failed to show a significant association between indices of cow comfort and certain cow behaviour, such as time spent lying. Obviously, it is not easy to assess cow comfort by scientific means, with no con-

sistent definition of what is to be assessed at hand. Thus, those who attempt to explain the term 'cow comfort' mostly use cow behaviour as basis of their explanations.

WEBSTER (1994), for instance, distinguishes thermal, physical and psychological comfort. Thermal comfort is supposed to be created by an environment that is neither excessively too cold nor too hot in extent or duration. Physical comfort, the author implies, needs to include access to a suitable resting area and freedom to perform activities such as feeding, drinking and excreting. Concerning the resting area, Webster ranks conditions of a resting area designed for dairy cows as follows: he believes hygiene to be the most important factor, followed by dryness, security and 'give' (in the sense that the mattress has 'give'); he reports that, given the choice, cows prefer beds that have the property of 'give'. Webster believes the cubicle or free stall to provide secure resting areas for dairy cows, which they can enter and leave as they please. Psychological comfort implies both a sense of security and absence of frustration. This depends on a proper balance between the reassuring company of familiar animals and the opportunity to create personal space as to avoid harmful contact with others. In contrast to most of the intensively housed farm animals, which experience welfare problems attributed to boredom, "the main welfare problem of the dairy cow is that she has too much to do" (WEBSTER 1994). In order to meet the energy demands of lactation, the cow needs to eat for long periods. In addition, she is usually expected to stand around in collecting yards for hours, awaiting entry to the milking parlour. All this reduces the time the cow can spend lying, which Webster considers to be a cow's first priority (WEBSTER 1994; similarly BERGSTEN 2001).

BERGSTEN (2001) states that cow comfort basically depends on two aspects: the softness of the ground surface and the condition for lying down and getting up. Problems with cubicle housing can include reluctance of the cow to lie down in cubicles, injuries and dirty cows. SUNDERLAND (2002) states that these problems mainly occur due to rather small cubicles, design of cubicle division and bedding as the modern cow is on average 15 cm taller and 30 cm longer from nose to tail than were cows in former times, but has inherited cubicle infrastructure that is often 30-40 years old (SUNDERLAND 2002; similarly FAULL et al. 1996). In his study, though, SUNDERLAND (2002) found that in terms of cow comfort it is much more important to provide comfortable and deep bedding in any cubicle than to make

cubicles bigger in size. This emphasizes BLOWEY's (1996) findings, who showed that cow comfort and bedding factors are more important than dimensions.

Cattle are social animals, living in stable groups with a clear dominance hierarchy. They have a rich social behaviour and a tendency to synchronize feeding and resting behaviour to ensure that the animals of a group will stay together (WIERENGA and BLOKHUIS 1997). Cattle spend a lot of time grazing (eight to twelve hours – if they can) and ruminating (four to eight hours); about eight to 14 hours per day are spent lying (WIERENGA and BLOKHUIS 1997). Dairy cows lie down for nine to 12 hours per day, with an average of 9.7 hours. The time cows spent lying and ruminating is longer than the time spent standing and ruminating. Cows lying down ten or more hours are more content with their environment and have fewer claw problems (SINGH et al. 1994).

Assuming that lying, walking and standing behaviour are all part of cow comfort, changes in these behaviours shown by lame cows would then mean a decrease in cow comfort for these animals. HASSALL et al. (1993) studied the behaviour of lame cows during the summer grazing period. They reported that during summer, lame cows lay down for longer and spend less time eating; they grazed more slowly, came later into the milking parlour than the others and were more restless when being milked. SINGH et al. (1993a) looked at cows' behaviour during wintertime, and compared the behaviour of normal cows in cubicles with the behaviour of normal cows in straw yards and the behaviour of lame cows in cubicles. They found that lame cows lay down for longer in cubicles than other cows in cubicles (although normal cows in straw yards tended to lie down for even longer), and moved about less, adopting abnormal postures when walking. In addition, lame cows were seen to be standing or lying in unusual postures, which the authors interpreted as signs of alleviating discomfort (similarly GALINDO and BROOM 2002). LEONARD et al. (1994) found that good claw health was correlated with more time spent lying down. PHILLIPS and SCHOFIELD (1994) showed that cows in straw yards tended to lie down for longer than did cows in cubicles; moreover, cows in straw yards had more opportunity to show their normal behaviour. SINGH et al. (1993b) compared the behaviour of cows while they were housed with their behaviour while being pastured. They found that cows lay down for longer when they were at pasture; the average lying time in cubicles was six to eight hours, whereas the average lying time on pasture was nine to 10.5 hours.

In terms of cow comfort, it can be useful to be aware of alterations in the cows' behaviour as they can be used to assess the degree of discomfort experienced by a cow during locomotion (O'CALLAGHAN 2002). O'CALLAGHAN (2002) concentrates on standing and walking behaviour as indicators of discomfort respectively lameness; she describes the following points as important: A sound cow walks with a level spine. She places her hind feet on almost exactly the same spots as the forefeet and the feet point in the direction she is walking. Her gait appears comfortable and she walks at a steady pace. On her way, she chooses a path around obstacles. According to the author, behavioural changes in lame cows include several aspects. The hind feet no longer trace the front feet position, and the length of the stride may shorten as lameness becomes more severe. The cow's head can be lowered or may nod during locomotion. Moreover, the spine may be arched. The cow may be walking more slowly and may select her path more carefully; often, lame cattle stop more frequently while walking. In order to transfer weight onto a healthy claw while walking, the cow may abduct or adduct her hind feet or cross the fore- or the hind feet during locomotion. At standing, the affected leg is often 'stretched' forwards or abducted to reduce the weight carried by the diseased digit without actually lifting the limb. In addition, the cow may repeatedly lift or paddle the lame foot. A combination of these changes is frequently seen in cows that appear sound at first. A cow that is affected on both hind limbs is less able to 'favour' one limb (i.e. to limp) and may adopt some of these alternative behaviours to express discomfort (O'CALLAGHAN 2002).

These different attempts in explaining cow comfort can be used to get near an understanding of what is defining cattle welfare and cow comfort. Moreover, changes in cow (comfort) behaviour can and should also be used in order to detect physical damages and diseases of dairy cows at an early stage. Among these – as the authors reviewed above found out – lameness as one of the most important problems in dairy herds is accompanied by behavioural alterations, too, such as changes in lying time as well as in standing and walking behaviour. These could be used in order to detect lameness at an early state, before limping (the so-called 'clinical lameness') becomes obvious. Instead of an assessment of cow comfort (which has obviously failed so far to prove itself working, probably due a shortage of definition), an assessment of thoroughly defined behavioural alterations should be used in order to detect diseases and complement lameness scoring systems, and to allow drawing reverse conclusions on cow comfort.

4. Definition of Pathology-Terms

Before any of the aspects related to the problem of lameness in dairy cattle can be discussed at all, it is necessary to define the terms ‘lesion’ and ‘lameness’. The proper definition of each of the two terms is a must, for lesions can occur that do not cause any lameness while lameness can occur without any traceable lesion. Or, as WEBSTER (2002) puts it, it is necessary at the outset to make a clear distinction between the description of diseases and disorders that present as lesions of the feet and leg, and the description of lameness, which is a disorder of locomotion.

4.1. The Term „Lesion“

Consulting Webster’s New Encyclopedic Dictionary, the entry for the term ‘lesion’ says: “an abnormal structural change in an organ or part due to injury or disease” (WEBSTER’S 1993). The Oxford Advanced Learner’s Dictionary (OALD) defines ‘lesion’ in a similar way as “harmful change in the tissue of a bodily organ, caused by injury or disease” (OALD 1992). A veterinary dictionary says that ‘lesion’ is “any pathological or traumatic discontinuity of tissue or loss of function of a part. Lesion is a broad term, including wounds, sores, ulcers, tumours, cataracts and any other tissue damage” (SAUNDERS 1999). Webster defines ‘lesions’ as diseases and disorders of the feet and/or the leg, thus relating it only to the area of the feet and legs, excluding the rest of the body. Lesions he presents as examples are: claw horn lesions, sole haemorrhages and White Line Disease (WEBSTER 2002). All these lesions are primarily mechanical in origin (WEBSTER 2002): the claw is damaged by mechanical forces, imposed either from above (e.g. the weight of the cow) or from below (e.g. the ground surface).

Although lesions may be followed by the occurrence of lameness, no high correlation can be recorded between the severity of the lesion and the severity of the follow-up lameness. In 1987, PHILIPOT et al. carried out a study in 160 French dairy farms in order to clinically characterize laminitis and heel horn erosion and to identify the risk factors of these conditions. In addition, they identified associations between different lesions and between lesions and lameness (PHILIPOT et al. 1994a). 896 cows were individually monitored during a five month period; eleven lesions were selected for the study: heel horn erosion, interdigital hy-

perplasia, detachment of the heel horn, sole ulcer, double sole, white line separation, yellowish coloration of the sole, haemorrhage of the sole, brittle horn, wall-rings, and dorsal concavity of the wall. Lameness and lesions were registered as absent or present regardless of their intensity (PHILIPOT et al. 1994a).

8% of cows were found to be lame during the survey; 89% of the cows were affected by at least one of the foot lesions mentioned above, with the prevalence of each lesion being very variable. Three of the lesions (dorsal concavity of the wall, yellowish coloration of the sole, and brittle horn) were not associated with lameness; eight of the lesions (heel horn erosion, white line separation, haemorrhage of the sole, wall-rings, double sole, detachment of the heel horn, interdigital hyperplasia, and sole ulcer) were associated with lameness. Only 11% of the cows observed did not suffer from any podal lesion (PHILIPOT et al. 1994a).

As can be seen, there are lesions that do not cause lameness and lesions that do cause lameness. As this study is concerned with the problem of lameness, lesions will only be dealt with if they are important in the context of the appearance of lameness. In order to be able to decide what lameness is, then, the term will be properly defined next.

4.2. The Term „Lameness“

‘Lameness’ as defined by a common dictionary is a physical disablement, “having a part and especially a limb so disabled as to impair freedom of movement” (WEBSTER’S 1993). Another dictionary describes ‘being lame’ as “unable to walk normally because of an injury or defect” (OALD 1992). John Webster puts it in a different way describing ‘lameness’ as “a disorder of locomotion, usually (although not necessarily) accompanied by pain” (WEBSTER 2002). GROEHN et al. (1992) defined lameness as “any abnormality in locomotion”, which comes close to Webster’s definition, although omitting the notion of pain.

Webster’s definition is also in accordance with the entry for ‘lameness’ in Black’s Veterinary Dictionary (1998); it says: “Lameness consists of a departure from the normal gait, occasioned by disease or injury situated in some part of the limbs or trunk, and is usually accompanied by pain” (BODEN 1998). As can be seen here, the concept of pain is inevitably connected with lameness; therefore, it will be dealt with later (see chapter 6.4.2.).

If viewed from the animal's point of view, the appearance of lameness has at least two meanings (although it is not proved that an animal really wants to deliberately express something by limping): first, lameness serves as a signal to the watcher, telling him/her, that something is bothering the animal somewhere in its leg or other part of the body, and is probably painful to the animal. Second, limping is a kind of strategy the animal makes use of to avoid something that is uncomfortable or even painful for it. By these 'definitions' lameness can be seen as a) a useful signal for the interested watcher, and b) – following Broom's definition of welfare (BROOM 1986) – as a strategy used in order to maintain a state of welfare, namely coping with the environment.

Taking all the above-mentioned notions concerning the term 'lameness' together, a definition of 'lameness' can be set as follows:

Lameness is a deviation from the normal gait caused by lesions, defects, injuries, diseases and/or other factors located somewhere in the limb or the rest of the body, and is accompanied by pain or at least some kind of discomfort. It serves as a kind of 'being bothered'-signal given by the animal (deliberately or not) to its observer and as a strategy used by the animal in order to maintain a certain state of comfort or even welfare.

So, as R. W. BLOWEY (1990) puts it, "even if you think an animal is lame in its head you should always examine its foot", which means in other words: one should take the limping of an animal serious and not think that it is malingering.

5. Clinical Forms of Lameness

Lameness is a symptom of different processes (HERLIN and DREVEMO 1994) and as such not a formal diagnosis (NOORDHUIZEN et al. 1996). It is the hoof and the area directly connected to it that is the origin of lameness in most cases (PETERSE 1992; LISCHER and OSSENT 2002). The origin of about 75% of all lameness recorded can be found in the claw region, including the deep flexor tendon and its components located in this area (ROSEN-

BERGER 1978); PETERSE (1987) even talks about 90%. Another 90% of cases of cattle lameness are due to foot lesions (O'CALLAGHAN 2002). Lameness caused by disorders in other parts of the locomotion system seems to be less frequent (PETERSE 1992); they make up only about 25 % (ROSENBERGER 1978). Lameness caused by disorders in other parts of the locomotion system than the claw is usually restricted to individual animals, whereas lameness caused by hoof problems more often occurs as a herd problem (PETERSE 1992).

85-90% of cases of lameness occur on the hind feet, and primarily on the lateral digit. With a base-wide stance, e.g. caused by increasing udder size, the soles of the lateral hind feet will carry excess weight (MANSKE 2002; similarly BERGSTEN 2001). If the cow abducts her rear leg and twists the toe outward, the inner claw still bears weight on the wall (as it is supposed to be), while the sole becomes less loaded; however, the weight distribution of the outer claw changes in that the weight moves from the outer wall towards the sole and backwards towards the heel. These processes change horn growth as well as blood supply, which can make the cow susceptible to diseases and processes causing lameness (BERGSTEN 2001).

5.1. General Description of Lameness

Lameness cases can be classified as either acute or chronic, depending on how it affects the cow in terms of speed of onset, severity, response to treatment and the duration of the recovery period. The term 'acute' describes a process that has been apparent for hours to days, whereas 'chronic' refers to a state that has lasted for weeks, months or even years (O'CALLAGHAN 2002).

Veterinarians use a certain scheme in order to describe clinical forms of lameness. SAUNDERS Comprehensive Veterinary Dictionary (1999) distinguishes forms of lameness as follows: 1) supporting leg lameness: "discomfort is evident when the animal is standing or bearing weight on the leg"; 2) swinging leg lameness: "abnormality of movement, such as hitching or failure to flex a joint, is evident when the leg is in motion"; 3) mixed forms of these two; 4) three-legged lameness: "the animal does not put weight on one of its limbs" (SAUNDERS 1999).

Besides these categories used by most veterinarians for describing a certain form of lameness, which relate to pain during movement and pain during weight-bearing, GREENOUGH (1985) suggests a different approach to describing bovine lameness. He believes that the bovine clinician needs to appreciate the significance of alterations in the quality of locomotion. Although he admits that this proposed form of evaluation is subjective, he believes it can work with observers who have gained some experience. Greenough categorizes lameness into four groups: 1) Aberrations of stride. In order to determine any changes in the features of a stride (e.g. the shortening of a stride), the observer should look at the animal from the side as it passes him. An evaluation of the movement should be made before and after examining the affected foot as manipulative procedures may alter the character of a stride. 2) Pain-dominated lameness. This term, as Greenough admits, is an arbitrary one; nonetheless, he thinks it can be useful as intense pain causes the animal to make a conscious effort to seek relief, thus providing the observer with useful information on the possible causal seats of lameness (GREENOUGH 1985). Usually, the more painful the animal is, the lamer the animal will be. 3) Specific lameness. A specific lameness is supposed to be one that produces a highly characteristic alteration in locomotion (e.g. luxation of the patella), and the diagnosis is based mainly on observation. 4) Characteristic stance. This is meant as a guide to diagnosis as it can indicate the probable seat of lameness; a certain way of placing the foot on the ground can refer to the area affected (e.g. if only the toe is weight bearing, the cow's problem maybe located in the hock or stifle) (GREENOUGH 1985).

Types of lameness can also be classified as trimming-related, infectious (e.g. digital dermatitis, interdigital dermatitis), due to claw horn lesions etc. (WEBSTER 2002; SHEARER and VAN AMSTEL 2002). Interestingly, lesions do not differ in their effect on the resulting grade of behavioural change or lameness; it is only the severity of whatever lesion that influences behaviour and movement of a cow (O'CALLAGHAN et al. 2003; see chapters 2.2. and 5.2.).

5.1.1. Claw Diseases Causing Lameness

The claws protect the distal extremity from wear and from contact with harmful substances in the environment, facilitate walking by ensuring a good grip, and act as shock ab-

sorbers (MANSKE 2002; similarly BERGSTEN 2001). There is a group of claw diseases that cause the clinical symptom of lameness; in fact, more than 90% of cases of lameness can be related to hoof lesions (BERGSTEN 2001). These have a major impact on the welfare of affected animals, because lameness is usually associated with substantial pain and discomfort (ALBAN et al. 1996). Based on an internationally agreed aetiological and pathogenetic standard (WEAVER 1994; MORTENSEN 1994), diseases causing lameness can be split up into primary and secondary disorders.

The following disorders are primary ones: dermatitis interdigitalis (footrot), dermatitis digitalis (Mortellaro disease), pododermatitis aseptica diffusa (laminitis) and phlegmona interdigitalis (foul-in-the-foot) (WEAVER 1994; MORTENSEN 1994).

Dermatitis interdigitalis is an inflammation of the interdigital skin without extensions to the deeper tissues. The infection starts in the skin of the interdigital space and progresses in the tissue along the coronary band (ALBAN et al. 1995). Disturbances in bulbhorn formation are possible; clefts in the bulbhorn can lead to bruising of the corium and, in severe cases, a sole ulcer might result (FRANKENA et al. 1993; GREENOUGH 1996). The cow is lame and often febrile; appetite is reduced and milk yield drops sharply. Foul-smelling exsudate is present (ALBAN et al. 1995). Primarily, dermatitis interdigitalis is a contagious disorder caused by *Bacteroides nodosus*, but *Fusobacterium necrophorum* might be involved as well (FRANKENA et al. 1993). *Bacteroides nodosus* is keratolytic and is possibly implicated as a contributory agent causing heel erosion (GREENOUGH 1996).

Dermatitis digitalis is an inflammation of the skin also called Mortellaro disease, as Cheli and Mortellaro were the first to report on this disease in 1974 (CHELI and MORTELLARO 1974). Typically, there are erosions or ulcerations of the skin bordering the plantar ridge of the interdigital space that are more or less circumscribed. The dorsal ridge is involved less frequently; sometimes, lesions are localised asymmetrically at the skin-horn-junction, proximal to the heel. Often, lesions are characterized by reactive or proliferative features and described, for instance, as 'strawberry-like' (MORTELLARO 1994). The aetiology seems to be multifactorial, with microorganisms being involved as well; one bacterium seems to be involved frequently, and was recently named *Treponema brennaborensis* (WARD 2001). The cow shows discomfort (the foot affected is rhythmically lifted from the ground) or is lame

(MORTELLARO 1994). The most common treatments for digital dermatitis involve the use of topical antibiotics and footbaths (BERRY 2001).

The term **pododermatitis aseptica diffusa (laminitis)** is applied to an aseptic inflammation of the dermal layers inside the foot (NOCEK 1997). It is a condition that causes impairment of the circulation of the horn-producing tissues. The clinical signs may be most severe, but the nature of the lesion is not visible or demonstrable (OSSENT and LISCHER 1994b). The pathogenesis of the disease is not certain; a multifactorial aetiology (consumption of concentrate high in energy, change of rumen environment, acute acidosis, circulation of vasoactive factors that interfere with the circulation of the corium) is being discussed. A phenomenon referred to as 'sub-clinical laminitis' was first described in the late 1970-ies. With this form of laminitis, the onset of the disease is insidious, and signs of the condition cannot be observed until it is well established (GREENOGH 1996; similarly GUARD 2001). The claw horn at the soles is softer than normal. Sometimes it can be yellowish in colour, probably caused by extravasation of serum from damaged blood vessels (PETERSE 1979), and may be blood stained (FRANKENA et al. 1992). Haemorrhages of the sole are considered to be a very significant sign of sub-clinical laminitis. Cows suffering from laminitis show a tender gait or even lameness (BOOSMAN et al. 1991).

Phlegmona interdigitalis is an acute inflammation of the tissues underneath the skin right above the horn capsule between the claws. It often starts with lesions of the skin that become inflamed by dirt and slurry. *Fusobacterium necrophorum* is supposed to be involved in the process, too. The condition is characterized by fissuring, caseous necrosis of the subcutis in the interdigital space and diffuse digital swelling (BERRY 2001). In most cases, antibiotic treatment becomes necessary (PETERSE 1987; WARD 2001; BERRY 2001).

Primary disorders can result in several secondary disorders or lesions, such as: pododermatitis circumscripta and septica (sole ulcer), white line zone defects, heel erosion and interdigital hyperplasia. A secondary lesion may be caused by one or more primary disorders (WEAVER 1994; MORTENSEN 1994).

Pododermatitis circumscripta (sole ulcer) is a defect in the sole horn with a contusion of the sole (WEAVER 1994), probably caused primarily by laminitis, poor horn quality and overloading of a limited area of the sole (HULTGREN and BERGSTEN 2001). Often, pus

can be found within the ulcer and needs to be released. Treatment involves removal of pressure by corrective trimming and often applying a block to the other claw in order to unload the affected one (WARD 2001).

White line lesions occur when the white line is separated and becomes wider than usual, consisting of rather weak horn. Stones and other foreign bodies can penetrate such a white line, causing haemorrhages, contusions and even abscesses. Treatment involves removal of under-run horn and usually some wall (WARD 2001).

Heel-horn erosion is an irregular loss of bulb-horn tissue (HULTGREN and BERGSTEN 2001). It can cause injuries deep in the hoof horn, which result in lameness. As in interdigital dermatitis, *Bacteroides nodosus* is believed to be the microbiological cause. Cows at their peak yield carry the highest risk of developing heel-horn erosions, possibly because they then have softer faeces and defecate more often. The lesions take at least two to three months to heal, because the injured horn must be replaced by sound horn; during the grazing season, they can heal spontaneously (BERGSTEN and PETTERSON 1992).

Interdigital hyperplasia develops from the small fold of skin in the interdigital space. It can become hyperplastic, (sometimes the horn too), leading to the development of small spikes irritating the skin. The lateral digit is more often affected than the medial; the condition is often secondary to interdigital dermatitis. Chronic irritation in the interdigital cleft, for example caused by interdigital dermatitis or by excessive splaying of the toes, may be a contributing factor. Cows show an abnormal stance or even lameness (BLOWEY 1994a; BERRY 2001).

5.1.2. Control of Claw Diseases

Most of the foot diseases mentioned above are most severe in the presence of unhygienic conditions, especially during the winter months (BRIZZI 1994). The amount of slurry should be reduced; in addition, the routine use of a footbath medicated with formalin has shown good results (BRIZZI 1994). The footbath should be used on a weekly basis starting in October. A more frequent use of the bath may be necessary later in winter, if the incidence of dermatitis interdigitalis increases (GREENOUGH 1996). In addition, floors and races should be kept as clean as possible as cleanliness and dryness of the floors are of major importance in the prevention of claw diseases, especially those with an infectious aetiology (BRIZZI 1994; see

vention of claw diseases, especially those with an infectious aetiology (BRIZZI 1994; see also chapter 6.1.3. and 6.1.4.).

Besides management improvement, a veterinarian should be consulted for treating any lame animal. There are several aspects the veterinarian has to consider in this situation. First, he should try and avoid the separation of the cow from the rest of the herd, as separated cows may become neglected or undergo a severe change in their food ration. This can be achieved by restoring a certain function in locomotion. Second, the veterinarian should do what is necessary on his first visit, including foot care, and thus limit further labour-intensive activities and thereby additional costs for the farmer (BRIZZI 1994). BRIZZI (1994) lists a few ideas as to what to do with a lame cow on the first visit; he calls these ideas “the ‘ambulating’ treatment of lameness” (BRIZZI 1994). He claims that on first examination, the veterinarian should establish an accurate prognosis and discuss the implications with the owner. He should then examine and eventually trim each foot of the patient, because there can be more than one foot affected. The affected claw should be trimmed functionally as to achieve maximum rest for it. The veterinarian should take care not to cause any haemorrhage so he can avoid bandaging. Bandages would need control, renovation and a dry environment, whereas an orthopaedic block fixed onto the sound claw does not need renovating and totally unloads the affected claw (BRIZZI 1994; see also chapter 6.4.). In addition, a sensible pain management should be part of any controlling operation on a lame cow (see chapter 6.4.2.).

TOUSSAINT RAVEN (1994) developed his method of the so-called ‘functional trimming’ in order to prevent and control lameness. He wants to control unsuitable horn formation by functional trimming, which he defines as a way of trimming based on the knowledge of the pathogenesis of the inflammations of the corium (TOUSSAINT RAVEN 1994) (see chapter 6.4.4.).

As far as laminitis is concerned, control has to be considered from several perspectives, as there are exercise and claw trimming. Another important factor in controlling laminitis is to balance a cow’s food ration in accordance with her nutritional needs; a diet containing enough fibre is important, for instance (see chapter 6.2.).

5.2. Lameness Scoring Systems

In order to be able to describe the grade of abnormality in locomotion, some authors have designed so called locomotion scoring systems (MANSON and LEAVER 1988a; TRANTER and MORRIS 1991; WELLS et al. 1993; WELSH et al. 1993; WHAY et al. 1997; SPRECHER et al. 1997). A routine program of scoring locomotion and recording lameness episodes within a dairy herd are important tools for the early detection of lameness and of any changes in the overall lameness rate within the herd (WHAY 1999).

There are some aspects concerning the locomotion of a cow that should be observed in order to detect any abnormalities in a cow's movements that may be indicative of lameness (WHAY 1999; similarly O'CALLAGHAN 2002):

- Hanging and nodding of the head while the animal walks – this becomes even more exaggerated in front limb lameness.
- Straightness or arching of the spine – an arched spine is frequently associated with pain in cattle.
- Tracking/shortening or lengthening of stride length – the hind foot is normally placed on the spot that the front foot has just left.
- Degree of abduction or adduction of the hind limbs – is it the same for both hind limbs?
- The ease and fluidity of movement.
- Willingness to walk.
- Alignment of the pin bone (tuber coxae) when walking – the pin bone on the sound side often sinks lower than the one on the affected side as the lame cow walks.
- How is the cow placing down her feet – does she e.g. throw them forwards to land on her heels or try to stand on her toes?
- Is lameness apparent – record which limb is affected.

In fact, there are too many factors to be considered to include all of them into a scoring system, but it may be useful to make a note of any particularly abnormal features that stand out when scoring a cow (WHAY 1999).

MANSON and LEAVER (1988a) devised a system of locomotion scoring, which has been widely used (WARD 1998). This system is based on the observation of cows walking away from the observer on a level concrete surface. Manson and Leaver used five scores, including half scores (so that actually there are nine scores available):

- 1.0 minimal abduction/adduction, no unevenness of gait, no tenderness;
- 1.5 slight abduction/adduction, no unevenness or tenderness;
- 2.0 abduction/adduction present, uneven gait, perhaps tender;
- 2.5 abduction/adduction present, uneven gait, tenderness of feet;
- 3.0 slight lameness, not affecting behaviour;
- 3.5 obvious lameness, some difficulty in turning, not affecting behaviour pattern;
- 4.0 obvious lameness, difficulty in turning, behaviour pattern affected;
- 4.5 some difficulty in rising, difficulty in walking, behaviour pattern affected;
- 5.0 extreme difficulty in rising, difficulty in walking, adverse effect on behaviour pattern.

A score of 3.0 or more is regarded as clinically lame by the authors. WHAY (1999) believes this system to be useful in identifying early signs of discomfort preceding lameness as half of the scores are dedicated to changes in gait prior to clinical lameness.

WELLS et al. (1993) refer to Manson and Leaver and develop a lameness scoring system that uses a five point system:

- 0 no gait abnormality (gait abnormality not visible at a walk; not reluctant to walk)
- 1 mild gait abnormality (mild variation from normal gait at walk; includes intermittent mild gait asymmetry or mild bilateral or quadrilateral restriction in free movement)
- 2 moderate gait abnormality (moderate and consistent gait asymmetry or symmetric gait abnormality, but able to walk without continuous stimulation)
- 3 severe gait abnormality (marked gait asymmetry or severe symmetric abnormality)
- 4 non ambulatory gait abnormality (recumbent)

As it is with Manson and Leaver's system, this one is another five-point system, and it, too, regards clinical lameness as occurring at the mid point. Unlike the previous system, this system starts at 0, whereas Manson and Leaver's starts at 1.

A similar system as the one designed by Wells et al. is the one by TRANTER and MORRIS (1991). They, too, use a five point system, also starting with a score of '0':

- 0 no abnormality of gait
- 1 lameness hardly noticeable
- 2 slightly lame
- 3 markedly lame
- 4 affected limb not weight bearing

The factors assessed with this scoring system are the degree and the timing of head movement, the degree of the sinking of the hind quarter, abduction and adduction, and changes in stride length.

WHAY et al. (1997) used a system originally devised for chicken, which is simpler than Manson and Leaver's. The five scores are claimed to present an evenly graduated score of clinical lameness (WARD 1998):

- 1 sound
- 2 imperfect locomotion
- 3 mild lameness
- 4 moderate lameness
- 5 severe lameness
- 6 as lame as possible while upright

According to WHAY (1999), this system was designed to be used for scoring cows that are walking abnormally, but are not apparently lame. The most obvious problem with this scoring system is that the scores are described but no exact criteria of assessment are given.

Thus, it depends on the observer's opinion which cow has to be graded 'mildly lame' and which 'moderately lame'.

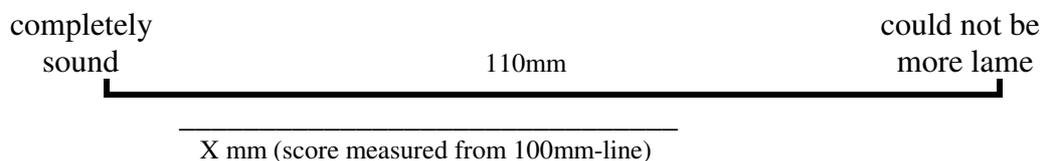
SPRECHER et al. (1997) developed a lameness scoring system in order to demonstrate the influence of lameness on reduction of fertility. He observed back posture and gait to produce a five-point score:

1	normal	The cow stands and walks with a level-back posture. Her gait is normal.
2	mildly lame	The cow stands with a level-back posture but develops an arched-back posture while walking. Her gait remains normal.
3	moderately lame	An arched-back posture is evident both while standing and walking. Her gait is affected and is best described as short-striding with one or more limbs.
4	lame	An arched-back posture is always evident and gait is best described as one deliberate step at a time. The cow favours one or more limbs/feet.
5	severely lame	The cow additionally demonstrates an inability or extreme reluctance to bear weight on one or more of her limbs/feet.

WARD (1998) says that this system is compatible with Manson and Leaver's as both describe a score of 3 or above as lame (WARD 1998). In their study, though, Sprecher et al. describes a score of 2 or above as lame. What is interesting about this scoring system is that Sprecher et al. introduced the idea of looking at the shape of the cow's back in order to identify lameness. This can serve as a sensitive method of spotting a lame cow, especially when both hind feet are equally tender (WARD 2001).

WELSH et al. (1993) developed a so-called visual analogue scale (VAS) for scoring lameness. They draw a 100 mm-line, the left end of which is named 'completely sound', the right end 'could not be more lame'. Underneath this line, the examiner has to draw a second line

line somewhere between the defined ends of the 100mm-line, representing his score of the observed cow.



This scoring system seems to be quite subjective as no clear definitions are set which length of the line represents which state of lameness exactly. Thus, this system may only be useful if it is always the same person who is scoring.

Another scoring system could find its way into cattle veterinary medicine, although it had been designed for grading horses suffering from laminitis: OBEL (1948) designed a system using the behaviour of a standing animal and its willingness to move as indicators of the degree of lameness (and pain) (OBEL 1948):

Grade 1: At rest the horse will alternately and incessantly lift the affected foot/feet. Lameness is not evident at walk, but a short stilted gait is noted at trot.

Grade 2: The horse moves willingly at a walk, but the gait is stilted. Man can lift one foot from the ground with difficulty only.

Grade 3: The horse moves very reluctantly and vigorously resists attempts to have one foot lifted.

Grade 4: The horse refuses to move unless forced.

These so-called Obel-grades may be useful in determining the grade of lameness in any cow during clinical examination, and may even be helpful in the judging of bovine laminitis, as this seems to be a similar process as laminitis in horses. What is more, some other techniques that are traditionally used in the examination of lame horses could be adapted to the examination of lame cows as well. WHAY (1999) suggests that if there is some doubt whether a cow is lame or if a bi-lateral lameness is suspected, gently walking the cow up and down a slope will exaggerate any signs of lameness. The same is true for walking the animal

over a rough uneven surface. Obviously this increases the discomfort of the cow and should not be used for routine locomotion scoring. Encouraging the cow to turn in a tight circle may also illuminate signs of lameness.

WHAY (1999) compared three scoring systems in order to evaluate the advantages and relative strengths of each method. By comparing MANSON and LEAVER (1988a), WHAY et al. (1997) and the VAS by WELSH et al. (1993) he tried to find out under what circumstances each system would be most effective. The comparison revealed that each of the three systems had specific strengths and weaknesses, but that none could be considered superior to the others. None of the methods used met each of the criteria 'accuracy', 'repeatability' and 'sensitivity' set by WELSH et al. (1993). The Manson and Leaver locomotion score was found to be valuable for scoring the early stages of locomotion changes rather than as a specific lameness score. Whay et al.'s systems proved to be the least sensitive of the three systems examined, but presented a more balanced focus on the scoring of clinically lame animals. The VAS was considered to be the most sensitive scale, but lacked the rigid structure that would limit drift in the scoring (WHAY 1999).

In order to achieve as much objectiveness as possible with any scoring system, the following requirements are indicated (WARD 1998):

- 1.) Cows are best observed when emerging from the milk parlour.
- 2.) The observer must not distract the cows so they walk in their normal single file.
- 3.) The cows are best observed on a flat and non-slippery surface, e.g. concrete.
- 4.) Cows freeze-branded on one or both rumps can normally be identified quickly at the same time as locomotion scoring takes place.

WHAY (1999) refined these requirements; he believes that carrying out whole herd lameness scoring and recording the results will provide essential information about changes in lameness rates over time and for comparison with herd incidence records. He thinks that it is important to keep records of each lameness scoring session and to be able to make comparisons between each session. Thus, he recommends the following points (WHAY 1999):

- Get information on the average prevalence of lameness within the herd. *First identify the problem, and then deal with it.*
- Get information on the relationship between lameness rates and the causes of lameness identified from the herd records. *Develop a strategy of lameness prevention specifically for the types of lesions seen on the farm.*
- Get information on changes in the total number of lame cows observed within the herd at any one time. *Is the situation improving? Have preventive measures worked?*
- Identify possible seasonal variations in the number of cows showing signs of lameness. *Target preventive measures to high-risk periods.*
- Use the same scoring system each time. *Choose a scoring system, or develop one, which can be easily remembered and applied quickly to the cattle being observed, which is repeatable and is also easy to record.*
- Score the cattle walking on the same surface all the time. *The ideal area is flat, well lit, non-slip, concrete, although other types of surface can help to reveal poor locomotion.*
- Try and have the same person or persons carrying out the scoring each time. *Lameness scoring is subjective and people have different perceptions of what 'lame' is. In order to make a valid comparison between current and previous lameness prevalence data the variability is reduced by using the same person to do the scoring. However, research has shown that with thorough training it is possible to compare scores recorded by different observers.*
- Ensure the information can be re-read and understood at a later date.

With his ideas on scoring cattle, Whay comes near to the modern concepts of the so-called quality management (QM) and the HACCP (Hazard Analysis and Critical Control Point) system already used in the food industry. He is interested in doing regular observations on the cows, on standardizing these observations, on recording them carefully and evaluating them in order to judge the state being. Identifying and characterising hazards, defining critical control points, developing measures to control these points, and documenting procedures and data are part of the HACCP system and the inherent risk assessment. This study will adapt both of

these systems to dairy cow lameness and try to develop a first step risk assessment (see chapter 7).

5.3. Recent Approaches To Lameness Detection

With all these 'traditional' systems there seems to be a lack of well-defined standards. These methods have to rely more or less on the individual skill of the person who observes the animal; there may be only few people who can observe and define subtle changes in the locomotion pattern of a cow, although WHAY (1999) claims that thorough training can teach most persons to do reliable lameness scoring. As obviously all scoring systems are subjective and depending on the examiner's skills and the cows' situation, it seems appropriate to match the scoring system used to the type of lameness information required and to the way in which the collected data are to be analysed (WHAY 1999).

This is what the study by FLOWER and WEARY (2006) aimed at by refining gait analysis. They tried a new approach to 'traditional' lameness assessment; they divided gait into specific gait attributes, scoring each attribute separately on a continuous scale, thus providing a more detailed profile of each cow's gait. The attributes they used were: back arch, head bob, tracking up, joint flexion, asymmetric gait, and reluctance to bear weight. The authors found that assessing specific gait attributes can be useful in distinguishing cows with sole ulcers from healthy cows.

HERLIN and DREVEMO (1994) came to similar results when looking back on the lameness scoring systems that were available so far. They wished to find a method that would be objective, exact and repeatable, and that would have an acceptable time resolution that allows detection of small movement alterations which the human eye cannot detect (HERLIN and DREVEMO 1994). They claimed to have found it in using high-speed cinematography and kinematic analysis. HERLIN and DREVEMO (1994) tried an investigation on the locomotion of 17 dairy cows by high-speed cinematography and kinematic analysis in order to find out about the long-term influence of management and housing on the locomotion of cows. They used three cows that were kept in tie-stalls all year long, six cows that were kept in cubicles and eight cows that were kept on grass. The cows were walked by hand of an experienced foreman along a 20 m track of level asphalt. The cows were filmed from a distance of 35 m

from their left side; the films were later analysed by a system for motion analysis. Although the number of the cows studied was relatively small, the authors state that the results of the study show that the different management regimes affected the locomotion, particularly some of the joint angle movements. They proposed their results to be useful in future kinematic determinations of normal and abnormal locomotion of cows. They suggest that quantitative methods for locomotion analysis – which are already in use for horses – may have a great potential and may be valuable for determining the effects of different management and housing systems on cattle. In 2005, FLOWER et al. also used kinematic measurements on cows, and found these measures to be objective and to be able to discriminate between healthy cows and cows with sole ulcers.

RAJKONDAWAR et al. (2006) tested another technologically supported way of identifying lame cows. They tried a system that automatically detects lame cows by measuring the vertical force components caused by an individual limb, i.e. they described how lame cows could be identified successfully by the loads applied to individual limbs when walking. According to the authors, these measurements can be used to calculate a number of limb movement variables. They investigated whether gait scores or lesion scores were more effectively captured by these variables and found that the accuracy of lesion-score models was superior to that of gait-score models. In spite of the less superior outcome for the gait-score model, this kind of automated lameness detection could have a future; further model development could actually generate automated and objective methods of lameness detection in cattle, thus minimizing the subjectivity connected to nearly each of the other models.

In 1998, WARD wrote that one way of assessing lameness in cattle and other species is to estimate the proportion of weight carried by an affected limb relative to a normal. Thus a cow described as three-tenths lame would be carrying seven-tenths of the normal weight, while one that is six-tenths lame would be carrying only four-tenths of the normal weight (WARD 1998) on the affected limb. This idea was taken up again years later. NEVEUX et al. (2006) used a force platform measuring weight distribution among limbs when cows are standing. They wanted to find out how cows redistribute their weight among their remaining limbs in response to discomfort in one limb. They trained Holstein dairy cows to stand on a platform with a soft rubber surface that measured the weight placed on each limb. The soft surface was replaced by an uncomfortable concrete surface under one or two claws and the resulting

weight shift was recorded. When one hind claw was placed on the concrete, the cows placed less weight on that claw and redistributed the majority of the weight onto the contralateral back hoof, but did not change the distribution of weight on their front hooves. When a front claw was placed onto the concrete, cows placed less weight on that hoof and shifted weight onto the contralateral front hoof and the ipsilateral back hoof. Cows placed more weight onto the back hooves when both front hooves were standing on the uncomfortable surface, whereas no change was observed when the back hooves were standing on concrete. The authors concluded that dairy cows remove weight from a limb in response to limb discomfort and redistribute this weight primarily to the contralateral limb, and have only limited ability to shift weight from back to front. They admit that lameness affecting both hind limbs may not be apparent in changes in weight distribution. Nonetheless, they believe that the implementation of such on-farm tools has considerable potential for treating and preventing lameness among cows in the dairy industry, given that further validation is done on this method and further development is sought in order to find out how weight distribution is connected with the presence of claw injuries (NEVEUX 2006).

MAZRIER et al. (2006) investigated the use of a pedometer (usually applied for oestrus detection in cows) for detecting lame cows several days prior to the onset of clinical lameness. The pedometric activity of each cow was recorded by computer, and the computer program they used was set to identify cows with a reduction of 5% or more in pedometric activity compared with their own previous ten day average; these animals were then examined for clinical lameness. 46 cows showed a reduced pedometric activity, and 38 cases of lameness were identified either by a reduction in pedometric activity or by clinical observation; of these, 21 lame cows (45,7%) showed a reduction in pedometric activity of 5% and more seven to ten days prior to the appearance of clinical lameness. In 92% of the lame cows identified by use of the pedometer, the decrease in pedometric activity was more than 15%. The authors concluded that although the pedometer did not detect all cases of developing lameness, it can be seen as a valuable tool for early discovery and treatment of developing foot lameness.

5.4. Conclusions

- Behavioural alterations (way of standing or walking, time spent lying etc.) should be taken into consideration in deciding if a cow is lame or is going to be lame.
- Each dairy herd should have a routine lameness scoring program that fits the needs of the herd (problems) concerned.
- Records of regular lameness scoring procedures should be taken in order to evaluate them concerning statistics and changes in the herd situation.
- A lameness scoring system should contain specific terms and detailed definitions of each of the scores to make scoring as objective as possible.
- Lameness scoring should be used for detecting lame animals, and, at its best, to detect animals showing changes in gait and/or behaviour, before they become clinically lame.
- Some methods used in examining lame horses could be adapted to the examination methods usually applied on cows, like the Obel-grades.
- Some kind of quality management program should be designed for each farm individually: the problem, the situation, the circumstances given, the goal to be achieved, and the measures that can possibly be taken should be defined and recorded carefully.
- Some automated methods to detect lameness are being studied already (load distribution, pedometers); they need to be refined in terms of reliability and practicability under on-farm conditions.
- It would be useful to develop a scoring system that takes single gait attributes into account; scores would thus become more detailed, and chances of detecting lame animals even at an early stage, would become greater.
- Negative effects of subclinical lameness on cow welfare should be investigated.
- Therefore, research should determine which gait attributes are necessarily needed in a composite scoring systems. Therefore, individual effects of claw pathologies on gait need to be identified.
- Research should evaluate how subjective assessments work when compared with more objective methods of assessing gait in dairy cattle; this seems necessary as in

an on-farm situation the more 'traditional' methods will still be mostly used as technical equipment (such as cameras or scale-platforms) will not be available.

6. Factors Influencing Lameness

Lameness means – in most cases – that there is pain in an animal, may it be acute or chronic (MUELLING and LISCHER 2002; WEBSTER 2002). As no animal should be forced to suffer from any such pain resulting in lameness it is important – besides releasing the animal from its pain, for example by medication – to reduce, or at its best, to eliminate factors influencing lameness in order to lessen the number of animals becoming lame. Knowledge of the factors influencing lameness might be used to reduce the incidence of lameness, and prevention is important in order to avoid chronic or repeated problems and thus poor welfare (ALBAN et al. 1996).

There are a number of predisposing factors that either separately or in conjunction with one another will influence the severity and the herd morbidity of lameness (GREENOUGH 1996). Potential causative factors include those related to housing, flooring, hygiene, daily exercise, nutrition, management and staff, veterinary and other care, and genetics.

6.1. Housing

Intensive milk production with high-yielding cows is increasingly carried out indoors through the whole year in Germany and The Netherlands, for example. This requires excellent housing, management and feeding to maintain proper hygiene and to avoid environmentally evoked diseases (HULTGREN and BERGSTEN 2001; similarly HARTUNG 1994). Foot, leg and udder disorders are among the most common production diseases related to imperfect housing, management and feeding (BERGSTEN 2001; HULTGREN 2002). An increased risk for lameness is found in large-sized and high-producing herds, especially herds that are housed (BERGSTEN 2001).

WEBSTER (1994) thinks that all houses for livestock represent a compromise between cost, operating convenience and animal performance, health and welfare (WEBSTER 1994; similarly BLOWEY 1994b). Nevertheless, there should be a way of finding the best compromise possible by creating a housing environment that equally meets the economic desires of the farmer and the health and welfare needs of the cows. Factors to be considered in optimising housing conditions are the type of housing (indoors or outdoors), flooring, hygiene, and daily exercise.

6.1.1. Housing – Indoors Or Outdoors

The increase in the size of herds and higher levels of management intensity have resulted in a gradual shift from pasture to confinement-type housing. Housing has its advantages, yet confinement often results in reduced cow comfort and more time on hard surfaces (SHEARER and VAN AMSTEL 2002).

Housing systems for cattle can be roughly subdivided into two categories: indoors and outdoors. Whereas outdoor housing can be equalled with keeping cows on pasture all year round (which is probably quite unusual these days), there are different forms of indoor housing with regard to the way cows can move around.

6.1.2. Indoor Housing – Loose And Tied Housing

There are two different forms of housing cows indoors: one, in which the cows can move around freely in certain areas specifically designed to meet the cow's needs for food, lying and walking; and a different one where the cows are tied in stalls. Within these two groups there are certain forms of each type. Loose housing can mean that cows are kept on straw yards or in cubicles (also called free stalls). Tied housing can be subdivided into short-stalls and long-stalls.

6.1.2.1. Tie-stalls

In a tie-stall each cow is tied at the neck by either a chain or a yoke; in most systems there is a partition between every second cow. The cows stand and lie on a wooden or concrete floor, which is raised 150-200 mm above a dunging passage. Cows are fed and milked in their standings. Straw is the bedding of choice, although dried bracken and sand can also be used (BLOWEY 1994b).

Recommendations for tie-stall designs seem to be varied, as only a few aspects of stall design have been investigated regarding their relationship with lameness, and most of the works involve free stall housing only. Few recommendations for tie-stalls are based on valid scientific studies (ZURBRIGG et al. 2005).

A so-called long stall is supposed to be 2.20 m long (HULTGREN 2001). ZURBRIGG et al. (2005) did a study in order to determine whether significant relationships exist between stall dimensions and dairy cattle lameness. They found that if tie-stalls are too short for the cow, the animal will stand for longer periods of time (instead of lying down) or will stand with its hind feet in the gutter; thereby, the hind feet are more exposed to urine and manure than when the cow would stand on a clean bed in a long enough stall.

It has become widely accepted that tethering cattle reduces their welfare because of the lack of freedom of movement (PHILLIPS and SCHOFIELD 1994), and during the last 25 years, the number of tie-stalls has dropped (EASTRIDGE 2006). Tie-stalls have been replaced by free-stalls as herd size has increased; yet, there are advantages and disadvantages to both forms of free stall housing, yards and cubicles.

6.1.2.2. Free Stalls

There are two forms of free stall systems: loose yards and cubicles. They both have specific areas for milking, feeding and lying. In a loose yard system, usually the whole area where the cows are stabled is surrounded by some kind of barrier or fence, with no additional fences to subdivide the space. So cows have an indoor paddock in which they can move around freely. Straw is the material used primarily for bedding in yards, although sometimes sand is used (mostly for open yards). BLOWEY (1994b) reports that straw requirements are high and can amount to half a ton of straw per cow in winter housing periods. The actual

amount depends on the length of the housing period, straw quality and yard stocking density. Yards should be bedded daily; BLOWEY (1994b), however, reports the frequency of cleaning out and re-bedding to be between every two weeks and once during the winter period, according to different authors.

In a cubicle system – a system developed by two farmers in 1960 (SUNDERLAND 2002) – there are feeding areas, passages and the so-called cubicles, which are individual stalls formed by barriers separating the lying area into individual places. Two rows of cubicles may face each other; the passageways, the dunging channel and the feeding area may have either concrete flooring or slatted flooring. The cubicles are usually floored with concrete, which requires additional bedding, normally by straw. Earth floors can be used, too, but cows tend to erode hollows with continual use (BLOWEY 1994b). Other factors influencing cow comfort in cubicles include the slope of the floor, cubicle size, the construction of the barrier, the amount of forward lying space and position of the neck rail, and cubicle management (for further information see for example BLOWEY 1994b; LEONARD et al. 1994; BARKER et al. 2007). Cubicles should be 2.3 to 2.4 m long and 1.2 m wide. The bottom rail should be at a height of 0.34 to 0.4 m, and the kerb should not be higher than 0.16 m (WARD 2001). FAULL et al. (1996; similarly MILL and WARD 1994) did a survey of cubicles; they reported that a cow requires approximately 2.40 on 1.20 cm lying space and a further 60 cm lunging space for rising. By these standards, the authors found 87% of the cubicles to be too short and 50% too wide or too narrow; only 12% of the cubicles observed allowed real freedom of movement.

The major differences between the two free stall systems are: first, the design of the lying area: cubicles have individual areas where cows can lie down, whereas loose yards allow cows to lie down wherever they wish to. So the amount and quality of personal space given to each cow is different, with cows in cubicles having less total space, but potentially more privacy. Second, there are differences in floor type, with cows in cubicles either standing on concrete or lying on a relatively hard bed, and those in straw yards spending nearly all their time lying or standing on soft straw. Both differences may have an influence on the cow's normal behaviour, e.g. interactive behaviour or lying time, and hence her welfare (PHILLIPS and SCHOFIELD 1994).

6.1.2.3. Lameness and Lesions: Relationship to Housing

Several studies have tried to observe relationships between the type of housing and the occurrence of specific claw lesions. Although this study is concerned with the problem of lameness, it is worthwhile considering these relationships, as there are lesions that result in lameness, as was already mentioned above.

As the incidence of lameness in dairy cows is reported to be higher during winter (while the animals are housed) than in summer, SINGH et al. (1993b) compared the behaviour of cows while they were housed with their behaviour while being pastured. They found that cows lay down for longer when they were at pasture and found more sole lesions during the wintertime than at summer. The authors concluded that lying down is an important factor in the occurrence of sole lesions, as prolonged standing on a hard surface may increase the frequency of sole lesions through alterations in weight distribution and blood supply to the claw (COLAM-AINSWORTH et al. 1989; SINGH et al. 1993b; similarly LEONARD et al. 1994). VERMUNT and GREENOUGH (1996) reported that indoor-housed heifers housed on concrete had a greater number of and more severe haemorrhages than heifers managed in a dry lot.

As far as tie-stalls are concerned, THYSEN (1987) found more leg injuries in tie-stall systems than in cubicles; ANDERSON et al. (1996) state that cattle housed in tie-stall barns are particularly susceptible to develop lameness.

In contrast to these findings, HULTGREN (2002) found a dramatic transitory increase in the incidence of foot and/or leg disorders when going from tie-stalls to cubicles; these results were gained from a study on foot and leg health in relation to housing changes in Swedish dairy herds carried out from 1988 to 1995. In the 1980ies and 1990ies, several other scientists found that clinical cases of foot and/or leg disorders are more common in cubicle systems or straw yards than in tie-stalls (ROWLANDS et al. 1983; THYSEN 1987; ALBAN et al. 1995). ALBAN et al. (1995) reported the incidence risk of interdigital dermatitis in Danish cows to be 3.7 times higher in loose housing than in short-stalls.

HULTGREN explains the “transitory deterioration of foot/leg health” (HULTGREN 2002) when changing from tie-stalls to cubicles to be possibly caused by e.g.: increased stress as a result of novel housing details and mixing of animals; cows not being used to moving around or standing on concrete; an increased wear of feet due to new concrete flooring; acci-

dents due to slipping; deliberately less frequent hoof trimming before the housing change to counteract the increased hoof wear on fresh concrete; and insufficient immunity (HULTGREN 2002). As these foot and leg effects were transitory, the causative factors must have diminished, either with time or altered behaviour of the farmer (HULTGREN 2002). ALBAN et al. (1995) explain the higher risk for interdigital dermatitis in loose-housed cows to be a result of increased faecal contamination, a higher degree of moisture and the possibility of movement in loose housing compared with tied-up stables. PHILIPOT et al. (1994b) found that changes in floor level were closely connected with the appearance of subacute laminitis. A high step down from a short stall to the dung channel, a height of the doorstep in cubicles of more than 20 cm, a doorstep at the entrance of the milking parlour of more than 15 cm height, or a step in front of the feeding trough – all these conditions force the cow to transfer their weight onto the hind feet either for a long time (feeding) or repeatedly (milking, lying down). Thus, the pressure on the tissue of the hind feet is prolonged and can cause bruises and subacute laminitis (PHILIPOT et al. 1994b).

Among the free stall systems, cubicles seem to be studied more often than yards, concerning their design, flooring and bedding. LEONARD et al. (1994) studied the effect of two different cubicle systems (one with rubber mat bedding, the other without any bedding) on foot lesions. They found a significant increase in the haemorrhages score of both groups after they were introduced to the cubicles, but scores became higher after a few weeks for the cows housed in the cubicles without bedding. This, though, may have been a problem of flooring rather than housing. LAVEN and LIVESEY (2004) investigated the effect of replacing rubber mats in cubicles by thicker mattresses filled with chopped rubber on the occurrence of hoof horn haemorrhages (white line haemorrhages and sole haemorrhages), but could not find a significant change in the development of hoof horn haemorrhages between the two beddings.

When comparing the two free stall systems (loose yards and cubicles), the incidence of lameness or lesions seems to be lower in loose yards than in cubicles. SINGH et al. (1994) reported that the incidence of sole lesions causing lameness was high when the farm had cubicles, but decreased markedly after the cows were changed to straw yards. BEAUDEAU et al. (2000) found that the incidence rate of lameness was higher in cubicles than in straw yards (similarly LIVESEY et al. 1998; WEBSTER 2001a; SOMERS et al. 2003). One explanation for these findings may be that straw yards result in a uniform distribution of weight between

the lateral and medial claws when the cows are standing, thereby reducing the incidence of sole lesions (SINGH et al. 1993a; WEBSTER 2002). WEBSTER (2002a) found that the severity of sole lesions in dairy heifers was reduced significantly by housing them in a straw yard between four weeks before and eight weeks after they calved, before they were introduced to cubicles (similarly FRANKENA et al. 1993; LIVESEY et al. 1998). Obviously, the occurrence of lameness cannot be attributed to the form of housing alone; flooring and calving are to be considered when talking about housing as well (for further information on flooring see chapter 6.1.3. Calving, days in milk and lactation number are factors influencing the occurrence of lameness and are closely related to nutritional concepts, for example; yet, considering this complex field of cow physiology here would go beyond the scope of this study. Therefore, for further information on calving, days in milk and lactation numbers see SINGH et al. 1993b, VERMUNT and GREENOUGH 1996, BERGSTEN and FRANK 1996; BLOWEY 1998; VOKEY et al. 2001; WEBSTER 2001a; WEBSTER 2002a; BARKER et al. 2007; HERNANDEZ et al. 2007, and others).

Reviewing the results of the studies mentioned above, it is rather likely that more cows are lame when the animals are housed in free stalls than when they are housed in tie-stalls, because lameness becomes far more obvious when the cow is moving around than when it is tied. In other words: the amount of lame cows was probably as high in tie-stalls as they were in the cubicles – but in the tie-stalls they were not detected as they could not move around freely. So, not only the type of indoor housing is responsible for a higher occurrence of lameness – other factors, as the type of flooring used, hygiene and management are closely connected to the housing problem.

6.1.3. Flooring

Changes in lameness frequency among the different housing systems should also be reviewed in the context of the different types of flooring used in the housing systems concerned. At the same time, the choice of flooring is closely connected to the form of housing (indoor or outdoor, paddocks, cubicles, free stalls or tie-stalls) and to the notion of hygiene. An ideal floor should be hygienic, comfortable to walk on, and have an even, skid-resistant surface

without being too abrasive. The floors should be cheap and simple to construct, durable, and easy to manage and maintain (BERGSTEN 2001).

Different materials are used for indoor housing systems: concrete, wood, sand, and rubber mats or mattresses of different quality. Nearly each of these materials can be used either as a solid covering of the ground for passageways and races, or as flooring for tie-stalls and cubicles (with or without bedding), or as a slatted floor. Certain floorings are only manageable in tie-stalls, whereas others, like soft grass and soil, are only available on pasture; concrete has long been the most common material for floors in confined systems, but softer materials may have their advantages, depending on the housing system and the state of hygiene possible in each context.

FAULL et al. (1996) conducted a survey of cubicles and indoor and outdoor walking surfaces; they found that 75% of cubicles had a concrete base and of those, 63% were judged to have too little bedding, and higher incidence and prevalence of lameness were associated with inadequate bedding. Out of 3335 outdoor walking surfaces, only 25% were classified satisfactory and 70% were found to be too rough; out of 3190 indoor walking surfaces they examined, only 25% were recorded to be satisfactory.

In indoor housing systems, tie-stalls and loose housing systems (cubicles and straw yards) can be distinguished. In tie-stalls, whether they are short-stalls or long-stalls, the flooring is made of concrete, wood, sand or rubber mats, mostly covered by a certain amount of straw or something similar as bedding. Depending on the original surface and on the depth of the bedding, these tie-stalls are more or less comfortable for the cow to stand upon and to lie down on (HERLIN 1994). HULTGREN (2001) found that cows on a rubber slatted flooring that made up the rearmost 0.74 m of the long-stall lie down and rise normally and slip less frequently than cows in long-stalls with solid rubber mats and chopped straw. RUSHEN et al. (2007) showed that cows in tie-stalls kept on rubber mats spend more time lying than cows on concrete (both floorings lightly covered with straw).

In free stalls and cubicle systems, passageways and races are made either of concrete or of some sort of slatted floor (concrete slats, wooden slats or rubber slats). Races made of concrete are given a rough brush finish initially that provides good footing for the animals. Yet, after years of cattle usage and mechanical cleaning with, for example, metal scrapers, the surface becomes smooth and slippery. On such a floor, cattle tend to walk cautiously, short-

stepped or on tiptoes, and this way of walking can result in malformed and overgrown claws. Thus, attention must be paid to keep races in an adequate fashion for the cows (AMSTUTZ 1987; similarly BERGSTEN 2001; WARD 2001). The incidence of claw horn lesions is greater in cows whose feet are exposed to hard concrete floors whether in stalls or on walking surfaces (WEBSTER 2001a; SOMERS et al. 2003). VERMUNT and GREENOUGH (1996) reported that indoor-housed heifers housed on concrete had a greater number of and more severe haemorrhages than heifers managed in a dry lot. AMSTUTZ (1987), BERGSTEN and FRANK (1996), and LIVESEY et al. (1998) stated that prolonged standing on hard floors has a negative effect on foot health and significantly increases the incidence of sole haemorrhages and White Line Disease. In addition, insufficiently drained and scraped alleys increase the risk of heel horn erosion and the need for veterinary treatment of other foot disorders when compared to concrete-slatted flooring (HULTGREN and BERGSTEN 2001; similarly FRANKENA et al. 1993; BERGSTEN 2001); these examples show that hygiene is at least as important as flooring (see chapter 6.1.4.).

The usual flooring for the passageways in a cubicle system is a slatted floor, sometimes combined with concrete flooring, mainly for the races. Concerning slatted floors, three characteristics and effects have to be pointed out: 1) The cow will theoretically use 70% of the claw to distribute her weight on, which increases the specific pressure on weight-bearing surfaces; actually, this is less than 70% and depends on the width of the slats; 2) The presence of dung and urine will make the surface more slippery; on the other hand, the slatted floor is relatively clean since the dung is tramped down, compared with solid concrete floors, where the dung amount is often higher, as it cannot be tramped through slats and needs to be scraped or flushed instead; 3) The quality of the concrete that the slats are made of also determines the slipperiness (HERLIN 1994).

Depending on the age and quality of the concrete, cows walking on it may suffer from higher horn abrasion and may develop bruises in their soles. This, in return, may result in restricted stride length and even more problems with tendons, joints and connected tissues. Besides hygienic advantages and disadvantages, slatted floors should be considered a matter of concern for claw health (WEBSTER 1994; similarly BERGSTEN 2001). HERLIN (1994) found a higher haemorrhages score in the white line zone of loose-housed cows, which he attributed to movements on the slatted floor. He resumed that this gives greater pressure on

the weight-bearing areas of the claw, as cows not even avoided the slots while walking (similarly VAN DER TOL et al. 2002). Slats should be wide enough to give sufficient support for the hooves (HULTGREN and BERGSTEN 2001). But not only the width of the slats and slots of slatted floors should be reconsidered in order to make movement easier for cows kept on such flooring, also the material used for slatted floors could use a revision.

The following study worked on exactly this problem. HULTGREN and BERGSTEN (2001) tested a manure-draining rubber-slat system on hygiene and foot health in tied dairy cows. This rubber-slat system is an alternative way of keeping a cow's stall clean and does not restrict the cow's room and movement. Traditional concrete or wooden-slatted floors have not been permitted for tied cows in Sweden.

The slatted floor used had nine rubber-coated, 53 mm wide slats with 29 mm wide slots between them. The manure gutter was lying underneath the floor. HULTGREN and BERGSTEN (2001) found the following: first, the cows' feet were significantly less dirty while they were kept on the rubber-slatted floor than while they were kept on a solid floor. Second, when compared to solid floors, the rubber-slatted flooring system was associated with significantly less occasions of dermatitis, sole lesions and heel horn erosion. The authors believe the improved foot health on the rubber-slatted floor to be caused by the improved hygienic conditions on the rubber slats (HULTGREN and BERGSTEN 2001). They found a higher dry-matter content of the claw horn in cows on rubber-slatted floor. This is in accordance with the findings of BERGSTEN and PETTERSSON (1992), who showed that cows kept in cleaner tie-stalls had a higher dry-matter content in their claw horn than cows kept in dirty stalls and who found a negative correlation between dry-matter content and the presence of heel horn erosion. However, HULTGREN and BERGSTEN (2001) admit, "if the stalls are kept relatively clean by other means, the effect of the rubber slats would probably diminish" (HULTGREN and BERGSTEN 2001). In other words: the important aspect in this context is hygiene again; the type of flooring is only one factor that can influence the cleanliness or dirtiness of a cow's stall. The rubber-slatted flooring is only one way of improving the hygiene in the stable without having to invest increased labour.

COOK et al. (2004) compared two free stalls, one with sand flooring, the other using rubber mats; they found that cows were lying for longer on the sand surface, and mean lameness prevalence was significantly lower in cows kept on sand than those kept on rubber mats.

Moreover, they reported that cows in sand stalls do not modify their daily routines when they are lame, whereas lame cows in mattress stalls spent more time standing than usual. Comparing cows in two free stall systems (one with concrete flooring, the other with rubber mats covering the entire concrete floor), VANEGAS et al. (2006) found that cows on concrete had a greater chance of developing heel horn erosions and of becoming lame than cows on the rubber surface. They concluded that a soft flooring surface is beneficial for hoof health. In contrast to this, VOKEY et al. (2001) did not find any benefit of rubber alleys in preventing clinical lameness.

FLOWER et al. (2007) studied dairy cows walking on concrete and on a soft, high-friction composite rubber surface in order to find out how different flooring influences gait and if this is different for cows with and without sole ulcers. They used a lameness scoring system to score the cows and analysed video recordings of the cows walking. The authors found that cows suffering from sole ulcers and walking on a composite rubber surface had longer strides, higher stride heights, more stride overlap, shorter periods of three legs in ground contact, walked faster, and had lower overall gait scores, better tracking up, better joint flexion, more symmetric steps and less reluctance to bear weight on their legs compared with the same cows walking on concrete. Similar results were found for cows without sole ulcers. When walking on the rubber surface, cows with higher gait scores (i.e. more severe lameness) showed the greatest improvement in stride length, periods of three legs in ground contact, swing duration, overall gait score and reluctance to bear weight compared with cows with lower gait scores. “These results indicate that rubber flooring provides a more secure footing and is more comfortable to walk on, especially for lame cattle” (similarly RUSHEN and DE PASSILLÉ 2006). TELEZHENKO et al. (2007) gained similar results from their study, comparing dairy cow preferences for rubber mats or solid concrete, and for rubber slats and concrete slats respectively. The authors found that a significantly higher proportion of cows stood on the soft and extra soft rubber mats than on solid concrete. When given the choice, a significantly higher proportion of non-lame cows walked exclusively on the side with the slatted or solid rubber mats than on the side with the slatted or solid concrete. Lame cows within a group of walking cows did not show a higher preference for soft flooring as distinct as normal cows, which the authors attributed to competition with higher ranked cows. “The majority of cows preferred to walk and stand on soft rubber than on concrete flooring”. In contrast to these

findings, FAULL et al. (1996) found that farms with the smoothest indoor walking surfaces had a significantly higher incidence of lameness.

Looking at the actual cubicles in a cubicle system, different types of flooring with or without bedding can be distinguished: concrete, sand or rubber mats and mattresses as flooring, which can (but need not) be covered with straw or something similar as bedding. LEONARD et al. (1994) investigated the effect of two different cubicle systems (one with rubber mat bedding, the other without any bedding) on foot lesions. They found a significant increase in the haemorrhages score of both groups after they were introduced to the cubicles, but scores became higher after a few weeks for the cows housed in the cubicles without bedding. LAVEN and LIVESEY (2004) investigated the effect of replacing rubber mats in cubicles by thicker mattresses filled with chopped rubber on the occurrence of hoof horn haemorrhages (white line haemorrhages and sole haemorrhages), but could not find a significant change in the development of hoof horn haemorrhages between the two beddings. WECHSLER et al. (2000) looked at cow behaviour and leg injuries in dairy cows kept in cubicles with straw beddings or mats/mattresses. Data were collected on five farms with deep straw bedding and on 13 farms using different sorts of mats/mattresses. There were no significant differences between cows kept in cubicle systems with mats/mattresses and straw bedding regarding the total time spent lying, but cows kept in cubicle systems with mats/mattresses had a significantly higher incidence of hairless patches and scabs or wounds, located mainly over the tarsal joints. The results indicate that mats/mattresses are equivalent to straw bedding in terms of cow behaviour but less favourable with respect to leg injuries (similarly RUSHEN et al. 2007). These findings are “in keeping with what many clinicians have observed in the field” (BARRETT 2002). Whatever the floor surface of the cubicles may be, bedding is essential to encourage cows to lie down (BLOWEY 1994b); a concrete surface sparsely bedded with a small amount of organic material can no longer be considered as an acceptable bed for a dairy cow (COOK et al. 2004).

6.1.4. Flooring, Bedding and Hygiene

Whatever the type of flooring used in a certain housing form is, its cleanliness and wetness influence claw health and locomotion of cows. Wet or slippery surfaces, paddocks filled

with mud or cubicles heaped up with slurry influence the occurrence of lameness negatively by their hygienic impact. Slurry may have a corrosive effect on the hoof horn (ČERMÁK 1994; BERGSTEN 2001; WEBSTER 2002), thus weakening the one important structure of the cow's claw that serves as a barrier against mechanical stressors from outside. The prolonged immersion of the cows' feet in filthy slurry has a marked impact on the appearance of diseases like digital dermatitis or claw horn lesions: immersion of the susceptible tissues of the foot in wet slurry on hard surfaces or wet bedding is responsible for initiation of the clinical disease (WEBSTER 2002). "The cow's foot was not designed for continued exposure to concrete 24 hours a day for 365 days per year and in housing conditions that subject the claws to constant contact with wet manure slurry. Present day housing and management practices common to intensive dairy production present tremendous challenge to foot health" (SHEARER and VAN AMSTEL 2002). Cows should be kept on dry and soft bedding for as much time per day as possible. WEBSTER (2002) puts it even more drastically: he claims that even if it is impossible to keep the feet of dairy cows completely clean, they should, as far as possible, be exposed to a dry and clean environment (WEBSTER 2002).

FRANKENA et al. (1993) found that a moist environment is especially predisposing for the development of dermatitis interdigitalis, because the horn becomes softer (BERGSTEN and PETTERSON 1992), and subsequently the resistance to physical, chemical and microbiological influences might be reduced. PHILIPOT et al. (1994b) found that poor hygiene, such as shortage of straw bedding, damp rear of cubicles, and narrowness of cubicles or stalls, was associated with heel horn erosion. BERGSTEN and PETTERSON (1992) showed that cleaner conditions of the stalls improved the condition of the hooves of adult cattle.

HULTGREN and BERGSTEN (2001) state that hygiene-related foot disorders are common during the housing season. They found that claws were significantly cleaner when cows were kept on a rubber-slatted floor than on solid concrete, because the faeces fall through the slots in a slatted floor instead of accumulating on a solid surface. PHILLIPS and MORRIS (2000) compared the locomotion of dairy cows on dry concrete floors with their locomotion on wet concrete and concrete covered by slurry. They found that wetting the floor did not affect the cows' walking and stepping rate, but reduced the swing arch of the legs; on the floor covered with slurry the cows' stepping and walking rates were reduced, and the step length was increased. RUSHEN and DE PASSILLÉ (2006) tested a rubber mat flooring on the lo-

comotion of cows. They found that cow locomotion was better on rubber flooring than on concrete. The covering of the walkway with a layer of slurry increased frequency of slipping, number of strides and time taken to pass the walkway; even increasing roughness and compressibility of the surface could not overcome the effects of adding slurry.

A traditional technique aimed at reducing the reservoirs of organisms on the interdigital skin is the use of footbaths. Permanently installed footbaths are more and more replaced by portable equipment. Formalin at a concentration of 5% is considered to be effective at a temperature of more than 13°C; they reduce the incidence of interdigital dermatitis (GREENOUGH 1996) and heel horn erosions (BERGSTEN and HERLIN 1994). Today, there are also minimal solution footbaths on the market that have a soft foam base lying beneath a waterproof membrane. When a cow steps into the bath the fluid moves to bath her feet. This bath needs only 10-15 litres of fluid compared to 125-200 litres in a traditional footbath. Fluid is used at the rate of about four litres for every 25 cows (GREENOUGH 1996).

Footbaths should always be placed at the exit of the milking parlour. Cleansing the digits by running the animals through a clear water bath prior to entering the parlour not only reduces the bacterial burden on the skin, but also extends the life of a medicated footbath by minimizing contamination of the bath with organic matter (GREENOUGH 1996). Baths that are contaminated with manure are ineffective (GUARD 2001).

Besides footbaths, electric trainers are used in many countries to help prevent the stalls of tied cows from becoming too dirty (BERGSTEN and PETTERSON 1992). These devices are used to train the cows to take a step back before urinating or defecating by conditioning them to avoid an electric shock. BERGSTEN and PETTERSON (1992) compared two groups of cows – one tied in stalls with electric trainers, the other tied in stalls without electric trainers – and investigated whether and in what way a clean respectively a dirty stall influenced the hoof health of the cows. The cows were tied from September to May and were turned out onto the pasture for the remaining time of the year. The authors found that the cows without trainers deposited significantly more dung-pats in their stalls than the cows with trainers, and that those cows without trainer were dirtier. In addition, they found a highly significant increase in the degree of heel-horn erosion among the cows without trainers between October and February, whereas the increase among the cows with trainers was low. Between February and May,

the trainer was introduced to some of the cows that had been without a trainer before. As a result, the degree of heel-horn erosion among these cows decreased significantly, while it continued to increase (although not significantly) among the cows that remained without trainers. During the same period, there was no increase in heel-horn erosions among the cows that had trainers throughout the period of housing (BERGSTEN and PETTERSON 1992).

BERGSTEN and PETTERSON (1992) concluded that the trainers were apparently successful in maintaining cleaner stalls. They found that whereas the cows with trainers required grooming only every eight to ten days, the cows without trainers had to be groomed every other day to remain satisfactorily clean, in spite of more straw being used for them. Moreover, the authors found that electric trainers reduced the prevalence of heel-horn erosions in a group of housed dairy cows. They conclude that correctly applied electric trainers can be regarded as a useful preventive measure against horn erosion in herds in which satisfactory results cannot be obtained by good management alone (BERGSTEN and PETTERSON 1992).

This conclusion should be reviewed in the context of the stable management system and the amount of work that can or should be done by the farmer and/or his staff. The authors' conclusion that despite good management no satisfactory results could be achieved in keeping the cows without trainers and their hooves clean is a bit vague. In fact, to be able to judge this conclusion, it would be necessary to know how frequently the stalls of the cows without trainers were cleaned and how much straw was used per day. Without this information it can only be assumed that even stalls of the cows without trainers could have been kept cleaner if more effort was made and more work done in cleaning the stalls and providing sufficient straw. On the other hand this would mean either a greater amount of work for one person or the need to hire more staff, which again would mean more costs and thus probably less income for the farmer himself.

Successful as the electric trainer may be in keeping the cows' stalls and hooves cleaner – it is nothing more than a technical means to make stable work easier and to decrease the amount of work and of labour. If electric trainers are used, they should at least be placed correctly, not be used for sick animals and be turned off for periods of time (ALBAN et al. 1996). In Germany, for instance, the use of electricity on animals is prohibited by law. An electric trainer is not the only way of keeping cows and their hooves clean and preventing the

development of heel-horn erosions, but it is a comfortable way for the farmer and the stockpersons.

6.1.5. Daily Exercise

Housing systems changed over the time from pasture to indoor housing. The main difference between the manifold types of indoor housing systems is whether the cows are loose or tied. If a cow does not walk far enough each day, as for example when space availability is reduced or they are housed on slats, they become more susceptible to lameness (PHILLIPS and MORRIS 2000).

There are four exercise levels imposed by the housing and management system. Exercise can range on a yearly basis from 1) the extreme zero exercise of cows kept permanently tied; 2) only seasonal exercise on pasture in summer; this is true for cows kept in tie-stalls in winter and on pasture in summer; 3) daily exercise of cows permanently kept indoors in cubicles; and 4) daily exercise plus additional seasonal exercise; this is true for cows kept in loose-housing during the winter and on pasture in summer (HERLIN 1994).

Cattle kept in a pasture environment have relative few lameness problems, whereas confinement, mainly dictated by economic demands, has increased lameness problems in dairy enterprises (AMSTUTZ 1987). PETERSE (1979) found that the prevalence of dermatitis interdigitalis decreased during the pasture period and increased again during the housing period in adult dairy cattle: prevalence of slight infections were 50% during the pasture period and up to 100% during housing; more severe cases showed a prevalence of 20% during housing and of almost 0% during pasturing. BERGSTEN and PETERSON (1992) and FRANKENA et al. (1993) even found that the prevalence of more severe cases of dermatitis interdigitalis increases during the housing period while the prevalence of lighter cases decreases. HERNANDEZ-MENDO et al. (2007) tested in their study whether providing cows with a four-week period on pasture would improve gait and change lying behaviour. By assessing lameness using gait scorings, the authors found that gait improved with those cows kept on pasture. From the four specific gait attributes they recorded (head bob, back arch, tracking up and reluctance to bear weight evenly on all four claws), the latter two also improved during pasture period. They concluded that a period on pasture could be used to help lame cattle recover.

As the authors observed the cows on pasture to spend less time lying than the cows indoors, they presumed that gait improvement was due to a more comfortable surface on pasture to stand and walk on (HERNANDEZ-MENDO 2007).

As BOCKISCH (1993) found out, the average distance covered by cows per day in a cubicle system was 600 to 700 m, with values ranging from 180 m to 2500 m per day. In countries or regions where no area for pasturing is available and cows are kept in tie-stalls and not in cubicles, regular daily exercise can be an alternative to a 365-days-tied housing system (GUSTAFSON 1993). Moreover, as GUSTAFSON (1993) found out, daily exercise is supposed to have a positive effect on the cows' general health (similarly BERGSTEN 2001).

In his four-year-study GUSTAFSON (1993) introduced 28 first calvers and 24 second calvers of the Swedish Red and White dual-purpose breed to the experiment. All cows were tied in the same building. According to their age at calving, month of calving, breeding value of the father and first lactation yield of the mother (each in descending order) the cows were randomly assigned to one of the two experimental groups: non-exercised (NE) and exercised (E). The NE-group only moved for weighing (once a week) and for hoof trimming (two to three times a year). The E-group was walked almost each day throughout the year, except when the walking alley was too slippery or temperatures were below -10°C (15-70 days). The cows walked three kilometres from May to October and 400 to 800 meters from November to April. In the alley water but not food was available. Except for the daily walking, staff members and management routines were the same for the two groups. GUSTAFSON (1993) concluded that health in general was significantly and positively influenced by exercise, and the need for veterinary treatment was reduced. The NE-cows were more affected by calving-related diseases, mastitis and leg-problems and needed significantly more veterinary treatment than the E-cows. This difference occurred entirely during weeks 0 to 2 of lactation. There were four cases of veterinary treatment due to leg disorders and three cases due to laminitis in the NE-group, whereas there was no case in the E-group, neither due to leg disorders nor due to laminitis. Cases of non-infectious leg and hoof disorders were also more frequent in the NE-group; they showed more skin lesions on the hock than the E-group. Sole ulcers were more frequent in the E-cows on one occasions of four because of problems with the surface in the exercise alley (GUSTAFSON 1993).

HERLIN (1994), too, found that exercise under loose-housing conditions and on pasture is positive for the cow. He concluded that the stiffer movement pattern of the walk he observed in permanently loose-housed cows on slatted floor may be a strategy to avoid slipping, but may also affect the weight-bearing of the claw. In addition he found that exercise on grass seemed to strengthen the tendons controlling the fetlock joint, suggesting relief of pressure on the sole of the claw (HERLIN 1994). HERLIN and DREVEMO (1994) came to similar results in their cinematographic study in the locomotion of cattle kept in different housing systems (see chapter 5.3.). ANDERSON et al. (1996; similarly SOMERS et al. 2003) found that cattle housed on concrete flooring with limited exercise are more likely to suffer from lameness than does cattle which is allowed free access to pasture. In 2004, REGULA et al. showed in a two-year study that the occurrence of lameness were reduced for tie-stalls with regular exercise throughout the year compared with tie-stalls with exercise during summer only.

In contrast to Gustafson and Herlin, ALBAN (1995) could not find any association between exercise (which in her study meant grazing) and the reduction of lameness. She explains that any positive influence from daily exercise was levelled out by the negative influence from, for example, small stones bruising the hooves (ALBAN 1995). Yet the author admits that exercise probably has a positive impact on the health of the cows' legs, but to be so the exercise area should be in a proper condition. GUSTAFSON (1993), too, stresses the proper condition of the surface of the exercise alley as an important factor. So, given an adequate surface condition, it can be concluded that certain daily exercise has a positive effect on the health of cows.

6.1.6. Conclusions for Housing

- Housing practice affects both the severity and duration of claw horn lesions.
- Tie-stalls are not acceptable in terms of animal welfare as they reduce free movement of cows.
- If tie-stalls are too short for the cow, the animal will stand for longer periods of time (instead of lying down) or will stand with its hind feet in the gutter; thereby, the risk of becoming lame is increased.

- Besides pasture, cubicles and free stalls are the housing systems of choice; they should be thoroughly designed and provide enough space; the free stall or cubicle, when designed properly and given a comfortable, hygienic bed, constitutes the best compromise between the needs of comfort, hygiene, economics and ease of management for most housed cattle.
- The number of cubicles in a cubicle housing should be the same as the number of cows stabled; no cow should be denied access to a cubicle and forced to stand in the passage by virtue of an absolute shortage of cubicles, passageways that restrict freedom of movement and encourage bullying, or simply through timidity and inexperience.
- The stocking rate should be investigated; to encourage lying down, cows should have ten percent more free stalls than the total number of cows.
- Comfortable lying places should be provided for every cow; choose cubicle size according to a cow's need of space.
- The relationship between cow behaviour and lameness should be studied as to gain useful suggestions for how housing systems for dairy cows may be modified or newly designed in order to reduce the incidence of health problems and improve the welfare of dairy cows
- Behavioural differences between housing and pasture should be minimized through cubicle and free stall design.
- Management solutions that reduce excessive standing and walking on uncomfortable floors must be encouraged.
- More research on a cow's standing behaviour should be done.
- Animals should be given some time to accommodate to a different floor surface, especially when they are changed from soft to hard floors. Heifers should be allowed to adjust to reduced exercise and walking on a concrete surface prior to introducing them to the dry-cow unit.
- Soft bedding is essential to claw health and cow comfort; straw yards are better than some cubicles in encouraging cows to lie down, and they are softer; yet, it is possible that if cubicle beds could be made as comfortable as a straw yard, cubicles might become as beneficial for a cow as a straw yard.

- As flooring, concrete is considered to be worse than rubber mats in terms of claw health and cow comfort.
- The applicability of soft surface areas in traditional concrete flooring systems should be investigated.
- Research on long-term benefits of rubber flooring should be done.
- Proper floor hygiene is beneficial for claw cleanliness and claw health; in both loose housing and tie-stalls measures should be taken to reduce the wetness and the faecal contamination of the floor.
- Regular exercise is beneficial for cow health and claw health; whenever no access to pasture can be permitted, exercise in specially designed areas is recommended.
- It is important to make sure the surface of the exercise area is dry and smooth in order to prevent it from causing hoof problems and in order to improve hoof health.

6.2. Nutrition

As well as cows should be kept on clean and dry beddings, nutritional balance should be checked upon regularly in order to meet a cow's needs. "It is impossible for us to ignore the influence of nutrition in any discussion of the welfare of the dairy cow" (LOGUE 1997), as proper nutrition management can lower the number of foot problems. Nutritional practices are recognized as the most important factor responsible for herd problems with non-infectious foot lameness (OLSEN 1997).

6.2.1. Nutrition and Metabolism

Modern dairy cows have an ability to yield very large amounts of milk at considerable expense to their body. The cow uses her body condition to balance input and output, and of course, there is a limit to the extent the cow can do this (LOGUE 1997). The most unusual feature of the metabolic load on the lactating cow is not the intensity of the metabolic load but the length of time it must be sustained. A chronic welfare problem of metabolic origin arises

when the cow becomes unable to meet the sustained physiological and metabolic demands of lactation and suffers a severe loss of body condition (WEBSTER 1997).

Management should adjust this situation of negative energy balance as dietary inadequacy can not only be a major constraint to performance, but also a potential source of distress and lameness (LOGUE 1997; WEBSTER 1997). An analysis of foodstuffs and dietary formulation can help to balance input, internal catabolism and output, so that the cow can cope (LOGUE 1997). According to EASTRIDGE (2006) the primary feeding system today is the total mixed ration, and improvements have been made in the use of protein, carbohydrates and fats in diets. Although advancements have been made in feeding practices to minimize the risk of metabolic diseases, these continue to be one of the greatest challenges in dairy cow nutrition (EASTRIDGE 2006).

With an increasing milk yield per cow, the dry matter intake of each cow has to grow, too. However, due to rumen fill or satiety, dry matter intake per cow is limited, so the energy density of a diet has to be increased. Nevertheless, forage and a high fibre level of the diet remain crucial in feeding a dairy cow (WEBSTER 2001a; EASTRIDGE 2006) as they help to maintain rumen health. Forages used for dairy cattle diets are alfalfa, whole plant corn, whole plant sorghum, cereal grains, and grasses (EASTRIDGE 2006). Forage particle size is important for rumen dynamics and rumen pH. Larger particles usually remain in the rumen longer, contributing to the floating rumen mat that helps trap small feed particles and slow their rate of fermentation. Inadequate particle size may result from too fine cutting in producing silage. Techniques for measuring particle size usually involve graded sieves, like a particle separator or shaker box. Attention has to be paid to the fact that large particles in the food delivered do not guarantee adequate particle size in the rumen as cows may tend to sort large pieces out (GUARD 2001).

Dry hay seems to be an important factor in protecting animals from metabolic disorders, and the exclusion of dry hay from the diet, possibly combined with a high-grain diet, increases the risk of lameness (AMSTUTZ 1987; GROEHN et al. 1992). FRANKENA et al. (1992) found a negative association between the feeding of hay as roughage and supplying concentrates and the appearance of sole haemorrhages (which are considered a sign of sub-clinical laminitis; see chapter 6.2.2.). Moreover, in 1993 the same authors were able to show that feeding of hay as roughage was protective for dermatitis interdigitalis (FRANKENA et

al. 1993). Whether from forage or dry hay, fibre levels must be measured correctly in order to be able to feed carbohydrates adequately. The non-structural carbohydrates should not exceed 40 to 45% of the ration, and the individual ration should be changed gradually depending on the needs of the cow (e.g. depending on whether a cow will soon be calving or not). In addition, each ration should be balanced for vitamins and minerals. VERMUNT and SMART (1994; similarly AMSTUTZ 1987; EASTRIDGE 2006) suggest to kept the roughage to concentrate ratio in the 40:60 or 50:50 range. AMSTUTZ (1987) recommends similar conditions. Yet, as EASTRIDGE (2006) claims, research has demonstrated that formulation of diets for a targeted forage-to-concentrate ratio is not adequate as it does not take into consideration the quality of the forage, the particle size of the forage, the type and processing of the cereal grains, and the concentration of non-forage fibre sources in the diet, which could affect dietary starch concentration.

High starch concentration in a ration, resulting, for example, from feeding high concentrate diets to dairy cows, is a factor predisposing cows to metabolic disorders and to lameness (LIVESEY and FLEMING 1984; BERGSTEN and FRANK 1996; OLSEN 1997). MANSON and LEAVER (1988a) compared two groups of cows on cases of clinical lameness. One group was fed a low concentrate ration, and the other group a high concentrate ration. There were ten cases of clinical lameness in the low-concentrate-group (seven of which were caused by sole ulcers), whereas there were 37 cases of clinical lameness in the high-concentrate-group (28 of which were caused by sole ulcers).

Although not understood in detail yet, there seems to be a link between metabolic diseases, i.e. ruminal acidosis (AMSTUTZ 1987; OLSEN 1997), and claw lesions (see chapter 6.2.2.). According to OLSEN (1997), the two primary categories of nutritional problems that are responsible for ruminal acidosis are: first, nutritional management practices which result in poor adaptation of the rumen to ration changes, and second, rations which predispose the cow to ruminal acidosis. Rations which cause ruminal acidosis can result either from errors in formulation or from errors in feeding of rations. The prevention of ruminal acidosis in cows depends on developing and feeding sound rations, so that the ruminal microbes can adapt themselves to the newly desired fermentation. The prevention of ruminal acidosis from a badly designed ration can be achieved by formulating rations that meet or exceed the minimal amount of acid detergent fibre of 21% of dry matter and neutral detergent fibre of 28% of dry

matter (OLSEN 1997). High-fibre diets encourage saliva flow, and bicarbonate in saliva helps to neutralize acid in the rumen (WARD 2001). Thus, a sensible nutritional management of a dairy herd can help in decreasing lameness occurrence. Yet, the relationship between nutrition and laminitis frequently remains unrecognised by the farmer because of the time lag between the nutritional insult and the subsequent lameness (OLSEN 1997).

6.2.2. Nutrition and the Problem of Laminitis

According to OLSEN (1997) and other authors, there seems to be a link between ruminal acidosis and bovine laminitis. The term pododermatitis aseptica diffusa (or laminitis) is applied to a condition that causes impairment of the circulation of the horn-producing tissues and an inflammation of the corium arising from a systemic disorder due to a wide spectrum of probably largely interdependent aetiological factors. These can be: metabolic and digestive disorders (consumption of concentrate high in energy, change of rumen environment, acute acidosis), parturition or severe inflammatory processes (e.g. metritis or mastitis), trauma to the claw, lack or excess of movement and others (BOOSMAN et al. 1991; OSSENT and LISCHER 1994a; VERMUNT 1994; GUARD 2001). These aetiological factors are supposed to result in a circulation of endotoxins and vasoactive factors that interfere with the micro-circulation of the corium (VERMUNT and GREENOUGH 1994), and trigger specific mechanisms that cause degenerative changes in the foot (NOCEK 1997). The clinical signs may be most severe, but the nature of the lesion is not visible or demonstrable (OSSENT and LISCHER 1994). VERMUNT and GREENOUGH (1994) and other authors consider sub-clinical laminitis to be the most important condition affecting the claws of dairy cattle; TOUSSAINT RAVEN (1994) states that cows suffering from laminitis are not the exception, but the rule in intensive dairy farming, and that about 90% of cattle lameness are caused by laminitis. Therefore, a short review of the problem will be given here.

Bovine laminitis can, according to VERMUNT (1994), be broadly classified into four forms: acute (as described above), subacute, chronic and subclinical. In the acute and subacute stage of the disease, an aseptic inflammation of the corium coincides with a systemically sick animal. Cows show a stiff and tender gait, an arched back and have the hind limbs placed well under their body; some animals prefer to remain lying (BOOSMAN et al. 1991).

The claw then shows little if any visible changes. These forms can easily progress to the chronic form (VERMUNT 1994). In contrast to the first two forms, chronic laminitis has no systemic symptoms, and changes are found only with the claw. A disturbed horn growth pattern and an alteration in claw shape (e.g. elongated with a flattened sole) are characteristic. Grooves and ridges can be seen in the claw wall that are close at the toe and diverge at the heel (VERMUNT 1994; similarly BOOSMAN et al. 1991; NOCEK 1997).

Peterse first described the phenomenon of subclinical laminitis in dairy cattle in 1979. With this form of laminitis, the onset of the disease is insidious, and signs of the condition cannot be observed until it is well established (GREENOUGH 1996; similarly GUARD 2001). Changes in posture or locomotion are rare, but significant changes in the claw horn are visible. The horn becomes softer and discoloured and can be stained yellow or by haemorrhages (PETERSE 1979; FRANKENA et al. 1992; NOCEK 1997; SMILIE et al. 1999). Subclinical laminitis can also progress into the chronic form of the disease (VERMUNT 1994). Haemorrhages of the sole are considered to be a significant sign of subclinical laminitis. Sole haemorrhages are used by many workers to evaluate the severity of laminitis in a herd of cattle (GREENOUGH 1996). PETERSE (1979), BRADLEY et al. (1989), GREENOUGH and VERMUNT (1991), GUARD (2001) and other authors have suggested, that subclinical laminitis, by affecting the quality of the claw's horn (HINTERHOFER et al. 2006), is a major predisposing factor of other claw problems, e.g. white line disease, sole ulcer, double sole and heel erosion.

Ruminal acidosis, acute or subclinical (NOCEK 1997) is considered to be a cause of (sub-clinical) laminitis. An excess of carbohydrate intake is one of the more traditional explanations on the aetiology of laminitis; this theory has been adopted from equine medicine as a source of information due to a lack of a reliable cow model (VERMUNT and GREENOUGH 1994). Starch overloading occurs either when animals that are not used to it are fed a high quantity of carbohydrates, or when the composition of the ration is changed too suddenly. Besides, the quantity and quality of roughage has been suggested another influencing factor. At least one third of the total dry matter intake of a cow should consist of roughage in order to guarantee good rumen function (NOCEK 1997).

It is assumed that the consumption of readily digestible carbohydrates leads to the proliferation of *Streptococcus bovis* and *Lactobacillus species* in the rumen. As a result, rumenal

acidosis occurs, a lot of lactic acid is produced, and gram-negative organisms are reduced in number, a process during which large amounts of endotoxins are being produced. These act on the walls of small blood vessels, and arterio-venous shunts are opened. As a result, the corium is no longer supplied with blood, the small vessels rupture and blood or blood fluids soak into the horn and the corium. This process causes pain by an increased pressure in the claw, and additionally, the corium is no longer supplied with necessary nutrients. Thus, only defective horn can be produced (MORTENSEN 1994; VERMUNT 1994; NOCEK 1997; GUARD 2001).

It is for anatomical reasons that the soft tissues in the hoof are in a unique predicament that renders them vulnerable to this cascade of events. One special anatomic feature of the claw is the fact that the corium (dermis) is sandwiched in between the narrow space between the pedal bone and the horn shoe. Any increase in the volume of the corium will produce increasing tissue pressure and induce pain. The volume of the corium will increase by oedema through vessel wall damage and unphysiological arterio-venous shunting, hypoxemia, haemorrhages and thrombosis. All these pathological mechanisms are triggered by certain vasoactive substances that have been released to the system by different mechanisms and ultimately cause degenerative changes in the epidermal-dermal junction of the claw (OSSENT and LISCHER 1994a).

Research has not fully established all links between nutrition and laminitis. Flooring conditions (especially concrete flooring) and hoof trimming are mentioned to be important factors influencing the occurrence of laminitis, too (BERGSTEN and FRANK 1996). Nonetheless, the results so far show that major changes in diet for cows and too low a quantity of roughage in the total ration should be avoided in order to prevent the occurrence of laminitis, and thus lameness.

6.2.3. Conclusions for Nutrition

- Thorough design of dairy cattle diets is needed.
- Diets must meet the individual demands of the cow for fibre and energy, according to her stage of lactation etc.

- An appropriate diet for the cow should be designed, containing enough fibre out of forage.
- Energy density must meet the cows' needs.
- Quality of food is important for cow health.
- Rations should be designed in order to prevent ruminal acidosis and laminitis.
- Changes in ration composition should be performed slowly to allow the rumen to adapt to the new composition.
- Particle size in ration should be thoroughly determined and should be high enough.
- A total mixed ration should be designed that meets the cows' nutritional needs; it may be necessary to produce different total mixed rations on one farm for different groups of cows.
- Accurate physiological diagnostic tests should be developed that will help detect subclinical acidosis and laminitis in a herd at an early stage.

6.3. Management and Stockmanship

The farmer and his stockpersons are considered to be an important part of a cow's environment (SANDØE et al. 2003), and good stockmanship is essential to a cow's well-being as the animal depends on the person looking after it. Some characteristics the owner and his staff should have are: competence, humanity and truthfulness, inherent qualities of the so-called stockmanship. Farmer and staff can play an important role in the development of a disease (PINSENT 1992).

Closely connected to stockpersons and stockmanship is the management type of a farm. There are factors like herd size, farming intensity, technical equipment or given environmental features that influence the health of a herd or an individual animal. Yet it still remains doubtful whether it will ever be possible to measure management to such a degree that all variation in disease occurrence can be explained (ALBAN et al. 1995).

6.3.1. Management

Management is a term under which several aspects can be subsumed. Housing and feeding a herd of dairy cows are two management tasks, and have already been dealt with in this study. The determination and control of the size of the herd, taking both stall space available and the amount of work to be done by a certain number of workers into account, are important for dairy cow welfare and the occurrence of lameness.

Over the past decades, the size of dairy herds has increased, and farmers have been confronted with higher levels of management intensity. Dairy cow management has undergone a gradual shift from pasture to confinement-type housing to meet the demands of higher management intensity. Under intensive housing conditions, a cow's resources, such as food and shelter, are distributed in a reduced space. However small the stall space given on a specific farm may be, it is important to provide enough space for each animal. First, this can be achieved by providing sufficient feeding and resting areas for all cows in the herd. DREW (1992) reports that there is a tendency for farmers to provide 5% less cubicles than there are cows in the group assuming that not all animals will wish to lie down at the same time. In overcrowded housing systems, it is the low-ranking cow that has to spend more time on hard surfaces, e.g. in the passageway, instead of being able to lie down (GALINDO et al. 2000). When heifers are kept in mixed groups with adult cows, not all heifers lie down in empty cubicles between older cows because they are lower in the herd ranking. To ensure that each cow has the opportunity to lie down whenever she wants, one cubicle (or resting place) should be provided for each cow and each heifer in the group (DREW 1992). Alternatively, heifers and adult cows should be kept in separate groups (WEBSTER 2001a; WEBSTER 2002b).

A second way of providing enough space for each cow on a specific farm is keeping cows in groups of minimal size (SAINSBURY 1992; HOE and RUEGG 2006). SAINSBURY (1992) recommends matching all animals in one group according to body size, body weight and age in order to keep fighting and bullying at minimum levels. The author believes these management procedures to be a good way of assuring controllable livestock keeping, as on overcrowded farms efficiency may decrease and health and productivity may be adversely affected.

The size of the herd is also important for the lameness detection ability of the farmer or stock worker. Larger herds (more than 99 cattle), on the one hand, may have managers who

are quite systematical at record keeping, but have fewer opportunities to watch every individual cow in order to detect lameness. On the other hand, smaller herds (less than 50 cattle) usually belong to a casual farmer who may not keep records at all or pay high costs for the treatment of lame animals. The 'in-between-herds' can pose a problem as they might be too large for a one-family unit to manage successfully, but may be too small to justify the hiring of extra labour (GROEHN et al. 1992). ALBAN (1995) found that the larger the herd, the more frequent is lameness. The author thinks that in a large herd more procedures are done by machines than in a smaller herd, and that a high degree of mechanization may reduce the time the farmer spends with each cow. This may result in a lower detection likelihood of lameness (ALBAN 1995).

FAYE (1991) states that there are not only relationships between herd size and cow health, but also between farm type and health profiles. Although the author doubts that the repeatability of these results can be claimed by means of one single study, he believes it possible to characterize the risks of disorders linked to types of farms. On the one hand, the study showed that health problems, especially lameness, tend to be more frequent on more intensive farms. On the other hand, the study showed that diseases do not necessarily have to be an inevitable result of more intensive farming, and that a farmer can improve the health situation of his herd by following the conventional rules of prophylaxis. This makes clear the strong connection between management and stockmanship, as every management system can only be as good as the person responsible for it.

Although FAYE (1991) took into account a lot of detailed features found on the different farm types, it would be indiscriminate to put each farm into one of the categories labelled 'high-risk production system', 'intermediate-risk production system' and 'low-risk production system'. First, there are too many too manifold variables making up each characteristic farm profile to allow the design of clearly defined farm-type-groups. In order to identify disease risks on a certain farm, results would be more accurate using a list of clearly defined risk factors as a basis rather than a list of farming types. Thus, any farm could be graded anew and individually as it is not pressed into a more or less vague and simplistic classification system, but is characterized by taking given system features into account and making up the 'overall risk' by grading the risk factors found on this specific farm. Second, a distinct definition of the term 'risk' would be needed, as well as a clear definition of what is acceptable and what is

not, in order to be able to judge any farm clearly. Third, any type of farm management can only be as good as the person performing and controlling it. In this context, it is the farmer respectively the staff who has to succeed in managing a farm. Some farmers may be better in mastering management and technical equipment than others. In any case, management and stockmanship are important to prevent diseases (AEBERHARD et al. 2001), and are closely connected in this context.

6.3.2. Stockmanship

Stockpersons are persons that take care of livestock; they feed them, move and handle them, and take care of their health through surveillance, cleaning and medical treatment. However, the description of these actions fails to capture the complexity of the relationship between stockpersons and the animals they look after (BOIVIN et al. 2003). As far as animal welfare in dairy cattle herds is concerned, the human-animal relationship is considered to be one important management and stockmanship factor (ROUSING 2003; ANTHONY 2003; BOIVIN et al. 2003; RENNIE et al. 2003). This relationship is determined by the stockman's mental and ethical attitudes towards the animal, by the way he handles the cows, by his knowledge, and by his willingness to learn.

ANTHONY (2003) believes that a relationship between a cow and a stockperson can exist in a similar way as it does between a person and a companion animal. The author views this so-called human-animal bond to be a starting point for ethical considerations of animal husbandry and for respectful treatment of cows as sentient beings. Thus, productivity and animal welfare would be increased. ROUSING (2003) is of a similar opinion, believing that recurrent adverse handling procedures will result in a complicated human-animal-relationship and fearful animals. SEABROOK and WILKINSON (2000) suggest that positive human contacts to cows will improve general animal care through earlier detection on individual changes, diseases and injury.

Good stock workers should be consistent in their everyday procedures and deal with the cows in a quiet and predictable way (BROOM 1992; BOIVIN et al. 2003). Staff members (and the farmer himself) can influence the frequency of lameness in their herd by the way they handle the cows. They can increase the frequency of lameness in their cows, e.g. by mak-

ing them hurry along their trail instead of letting them go at their own pace (CHESTERTON 1989; WARD 1994; GREENOUGH 1996; WARD 1999; WARD 2001). Observations of cows walking along tracks show that when they are allowed to go at their own speed, they look at the ground carefully, placing each front foot on the best spot and avoiding stones (WARD 1999). CHESTERTON (1989) showed that the distance cows walk influences the appearance of lameness as well, especially if the trail consists of mere concrete or has a slippery surface. So, attention should be given to the length of the trail and its quality as well as to the way cattle want to walk.

In some cases, the stockpersons prolong the lameness of an animal by controlling the herd insufficiently and overlooking lame animals. HULTGREN (2002) states that farmers differ in their ability to detect diseases and in how often they call a veterinarian when health problems occur. WHAY (2002) reported that farmers, on average, identify less than 25% of the lame cows in their herd, and clinical lameness that is recognized by most farmers is considered to be only the tip of an iceberg (WEBSTER 2002). ALBAN (1995) states that lameness accounted for 7.5% of all veterinary treatments, but for 24.7 % of all disease-days recorded by the farmer. Even the farmer's expectations concerning his future (and thereby his motivation on caring for his cows) may influence the frequency of lameness in a herd: cows belonging to a farmer who does not expect to be a dairy producer five years ahead have higher frequency of lameness than do cows belonging to a farmer who expects to continue being a dairy producer for more than five years ahead (ALBAN 1995). The dairy farmer might not consider lameness as important as other more frequently occurring diseases such as mastitis or reproductive problems, due to the slow onset of some causes of lameness.

It can be concluded that the amount of lameness in a dairy herd is closely related to the farmer's knowledge, training and awareness (MILL and WARD 1994; GREENOUGH 1996; MAIN and WHAY 2004). WARD (1994) collected results from different studies on the relationship between stockmanship and lameness in cattle. He reported that farmers who knew more about lameness and foot lesions than other farmers in their group had a lower prevalence of lameness in their herd. Farmers with more training in foot lameness and claw trimming also had a lower prevalence of lameness in their herd. The same was true for farmers with a better awareness of lame cows in their herds. WARD (1994) concluded that stockmanship is a very important factor in the prevalence of lameness. MILL and WARD (1994) sup-

ported these findings with their study. They found that the farmers' knowledge was low on farms with a high prevalence of lameness and vice versa. One farmer in their study could recognize a lame cow before it would start limping, and this farm had the lowest prevalence of lameness. The authors called it "an indication of poor stockmanship" (MILL and WARD 1994) if a farmer is not able to notice the physical signs of lameness when he watches the cows walking.

It is important to teach the farmer how to determine if an animal is lame or not. WEBSTER (2002) states that most of those who look after cows on a day-to-day- basis seriously underestimate the number of animals experiencing the pain of lameness. MILL and WARD (1994; similarly BOIVIN et al. 2003), too, believe that there is a great need for extra training for farmers and stockmen to increase their awareness and to teach them to recognize and to deal with lameness. Therefore, a farmer should record all lameness problems occurring on his farm, for example by using locomotion scores. For recording data, written papers, hand-held computers or other computer systems can be used. The motivation for applying one of these procedures should be to continuously increase the understanding of the causes and mechanisms involved in bovine lameness for a better chance of diagnosis and more effective prophylactic measures (MUELLING and LISCHER 2002).

Veterinarians could and should help farmers improve their knowledge, training and awareness of lameness, so that the prevalence of lameness could be reduced. MILL and WARD (1994; similarly BOIVIN et al. 2003) reported that farmers would like to know how to cope with lameness and how to decrease its prevalence for reasons of welfare and economics. Many dairies simply turn lame cows out into a lot where they remain until a commercial hoof trimmer or veterinarian can attend to them (SHEARER and VAN AMSTEL 2002; similarly ENEVOLDSEN and GROEHN 1991). The correct identification of e.g. claw problems requires careful examination of the claw, which might be difficult for the farmer to carry out (ALBAN et al. 1996). To improve the situation, employees should be trained in foot care and should be able to examine and treat lame cows on a daily basis. For this, they need handling and restraint facilities (i.e. a tilt table) and proper equipment, like hoof nippers, knives and sharpening devices (TOUSSAINT RAVEN 1994; SHEARER and VAN AMSTEL 2002).

Competent and sensible stockmanship is crucial for improving the welfare of dairy cows. It can contribute to prevention of disease, improved production and improved product quality.

It can also improve job satisfaction for the stockpersons. However, the trend in modern husbandry is to increase working time for the stockpersons by reducing the number of workers and increasing the number of animals per farm. Thus, according to BOIVIN et al. (2003), one of the major questions for the future is ‘What is the number of animals that a stockperson is really able to care for with respect to animal welfare and productivity?’.

6.3.3. Conclusions for Management and Stockmanship

- Herd size should be kept at a manageable level for the stockpersons.
- Herd size should be chosen according to the stall space available, or enough stalls should be provided, i.e. one for each cow to ensure that cows can lie down.
- Stockpersons should handle cows in a consistent, responsible and sensible way.
- Stockpersons should not make cows hurry along their track or treat them mean.
- A stockperson’s way of handling cows can be a risk factor for the occurrence of lameness.
- The closer the human-animal relationship between stockperson and cow is, the earlier and the more reliable will the detection of health problems, e.g. lameness, be.
- Stockpersons should be trained at identifying lame cows at an early stage.
- Stockpersons should improve their knowledge about lameness, handling facilities and methods to treat a lame cow correctly.
- Stockpersons should record the lameness status of each cow regularly.
- A list of risks that can occur on a farm should be designed in order to categorise farms according to their risk intensity to animal health and welfare.

6.4. Veterinary Care and Claw Trimming

Whenever a farmer or a stockperson is not able to treat a sick or lame animal himself, he consults a veterinarian. The veterinarian is responsible for maintaining a high health status of

farm animals (BAUMGARTNER 2002), and his constant endeavour should be to ensure the welfare of animals under his care (WEBSTER 1997).

In terms of cattle lameness, veterinary care has to comprise the examination of individual animals as well as the concern for herd problems. The management of pain – either for an individual cow or for the whole herd – is a central issue, as lameness is a condition accompanied by pain (MUELLING and LISCHER 2002). Thorough veterinary care and treatment can help to prevent cows from suffering from lameness, and claw trimming on a regular basis can be useful to prevent lameness, too.

6.4.1. The Role of the Veterinarian

Today's veterinarians should be dealing neither with a herd problem only nor with an individual animal's problem(s) only. The optimal way of checking on a herd of dairy cows is to a) consider the problem of the individual animal, b) check other animals in order to detect a possible herd problem, thus using a combined procedure to do justice to the individual animal as well as the farmer's whole stock (PINSENT 1992).

6.4.1.1. Veterinary Herd Health and Production Control

When a veterinarian looks at a herd of cows, he has to adopt an inquisitive, questioning, curious and observant attitude. Veterinarians should be critical, should notice everything around them and, if possible, be able to explain it (PINSENT 1992). The veterinarian has to consider the environment in a manner as critical as he considers the animal (PINSENT 1992; VERMUNT and SMART 1994). Advice on husbandry methods can be an important veterinary service, and the veterinarian should judge the animal's environment on whether or not it is suitable for the animal and on whether or not it can cause disease and lameness (BROOM 1992; PINSENT 1992). In this context, the bovine practitioner should be well aware of the clinical picture of the effects of housing and feeding on foot lameness in dairy cattle (WEBSTER 1997). In order to judge his impressions adequately, the veterinarian sometimes needs to try and take the animal's viewpoint; or in other words, "if it is thought that the ventilation

in a calf house is suspect, it may well be advisable to get your head down among the calves” (PINSENT 1992). The same accounts for the slipperiness of a floor or other factors influencing lameness.

Apart from veterinary knowledge, the veterinarian is required to apply agricultural and economic thinking to meet modern dairy farming demands. He needs to understand the productivity of healthy animals as well as the loss of production from sick ones (NOORDHUIZEN and BRAND 1983a; CANNAS DA SILVA et al. 2006). In this context the veterinarian is in a strategic position: by examining the animals he can provide up-to-date information, due to his regular visits he is familiar with the farm situations and might serve as a coordinator between the farmer, official persons and himself. The time spent on the farm by the veterinary practitioner conducting a herd health and production management service should be organized around the primary activities of rendering clinical and preventive service, data collection, decision making and advising (GUARD and BRAND 1996). Thus, a herd health service can function (1) to monitor and control each farm aspect from one farm visit to the next and over longer periods, (2) to detect unwanted situations or problems at an early stage, and (3) to serve as basic information for problem analysis (NOORDHUIZEN et al. 1983b).

One aspect to which veterinary herd health can prove beneficial is lameness in a dairy herd. Since cattle must always walk to function, the claw and leg health status should be included in a herd health and production management service (NOORDHUIZEN et al. 1996). By controlling lameness in a herd, reproductive features in the same herd will be influenced as well. NOORDHUIZEN et al. (1983c) explain that lameness will reduce the expression of oestrus and oestrus detection rate and may be a reason for unwanted culling of highly fertile cows. Furthermore, lameness has a negative impact on feed intake, milk production, udder health, and body condition. A veterinary herd health program can help optimise farm management and milk production: it enables the veterinarian to examine possible relationships between lameness and feed intake, milk production, udder health, conception or body condition and it combines data on farm management, animal health, milk production and farm economics. Thus it makes sound management decisions possible. Moreover, it can provide an optimal cooperation between the veterinarian and the farmer (NOORDHUIZEN et al. 1983a). It is likely that a single herd examination will produce leads that may then need to be fol-

lowed by further investigations involving a multidisciplinary approach such as involvement of a nutritionist or a farm-building engineer (VERMUNT and SMART 1994).

The veterinarian needs to spend more time and effort with the herd health program than he does with the occasional visits done to the herd traditionally. The assistance that the veterinarian has to provide in order to solve an acute problem or to prevent lameness from becoming a future cause of suboptimal feet and leg performance, also requires a good understanding of the pathogenesis of the disorders and of the environmental factors involved. Therefore, additional training in diagnosing, treating and preventing these disorders is necessary (NOORDHUIZEN et al. 1996; CANNAS DA SILVA et al. 2006). The veterinarian must always find ways to improve the suitability of the information to the dairyman, to enhance his motivation in a positive sense and to provide him with advice that is soundly based on true arguments and is economically justified. Many farmers seem to be interested to learn about how to improve the health standard of their herd (ČERMÁK 1994), and dairy farmers ask for support in areas like welfare, nutrition, grassland management and economics (CANNAS DA SILVA et al. 2006). A farmer may have saved direct expenses for veterinary interventions on short terms, but at the same time his herd may run a higher risk of lameness problems in the long run. It is the practitioner who has to point out to the farmer the benefits of a proper foot health status in terms of economics and animal welfare (NOORDHUIZEN et al. 1996).

6.4.1.2. Clinical Examination of a Single Cow

Besides taking care of a whole herd of dairy cows, the veterinarian also needs to examine single animals if necessary. Clinical work on a single cow should be a routine of examination that covers all eventualities. It is necessary to work with care, patience, thoroughness, methodologically and with logical routine and to develop an individual procedure in order not to overlook certain aspects (GREENOUGH 1985; PINSENT 1992; VERMUNT and SMART 1994). PINSENT (1992; similarly DESROCHERS et al. 2001; GUARD 2001) suggests some important elements that are necessary for a thorough clinical examination; these are: the owner's message, the animal's or the herd's history, a formal description of the animal or the herd, a preliminary inspection (which can be taken out during history taking), a preliminary examination, a systematic examination, and, if necessary, laboratory or specific examinations.

GREENOUGH (1985) summarizes the method with which a veterinarian should initiate the examination of a lame animal as “observe the observable and then confirm that which you think that you have observed as being a correct observation” (GREENOUGH 1985). As veterinarians spend most of their lives diagnosing disease, they need to understand that health is normality, and disease can be seen as deviation from normality (PINSENT 1992). Thus, in order to detect and recognize disease, veterinarians need to know what the normal state is. PINSENT (1992) believes that it is important to consider that normality is relative, not absolute: it is relative to age, breed, nutrition, management, the state of lactation or pregnancy, and a lot of other factors.

DESROCHERS et al. (2001) present a rather structured lameness examination in cattle. They regret that the mere physical examination usually performed on cattle lacks the specificity with which equine lameness-examination procedures are done. Yet, they admit, this system has not become routine standard in cattle lameness examinations as cattle are rarely halter-trained and do not tolerate limb handling followed by controlled walking or trotting. Moreover, cattle are less frequently presented to the veterinarian for subtle diseases causing mild lameness than horses are. The authors propose the following steps when performing a systematic lameness examination on cattle: First, a thorough history of the individual animal and the farm is important in order to refine the differential diagnosis of lameness. Second, the animal should be observed from a distance for a few minutes, in the stall as well as while walking, taking posture and gait into consideration. While examining the cow during movement, the veterinarian should observe the gait and assess the severity of the lameness and to determine which limb is the affected one. This limb should then be examined carefully, e.g. by using a hoof tester, applying firm pressure on soft tissues, palpation and eventually the use of a hoof knife. For this purpose, the cow can be placed in a standing claw trimming chute or a similar facility. Selective perineural anaesthesia (common practice in equine medicine) can be used to isolate the region causing lameness, and further diagnostic test can be done as well (DESROCHERS et al. 2001; similarly, but more focused on possible aetiologies: GREENOUGH 1985).

While examining a cow in order to find the cause of lameness, a veterinarian should always bear in mind that an animal that is lame, is suffering from some degree of pain. Not only the causal diagnosis is important in veterinary examination, the bovine practitioner also needs

to judge the degree of pain in a lame animal to form an impression of the cow's situation as a whole. To do justice to the animal and not limit its well-being to too large an extent, the veterinarian needs to have a distinct understanding of the notion of pain and the way cattle experience pain and react to it.

6.4.2. Veterinary Pain Management

'Pain' is defined as "physical suffering or discomfort caused by injury or disease; feeling of suffering or discomfort" (OALD 1992). As it is the accepted viewpoint of veterinarians, animals that are lame usually suffer from some degree of more or less severe pain (MUELLING and LISCHER 2002). WEBSTER (2002) states that the appearance of lameness in farm animals is usually a manifestation of severe pain rather than some mechanical disorder, and FITZPATRICK et al. (2002) claim that pain is a significant contributor to poor welfare, which can be considered an unacceptable condition (MUELLING and LISCHER 2002).

6.4.2.1. Cattle and Pain

It has not been for long that people actually believe and recognize that an animal can indeed feel pain and suffer from it. Attitudes towards animal welfare and pain stem from cultural, historical and socio-economic influences (O'CALLAGHAN 2002). Traditional perceptions of an animal as a creature unable to feel pain were challenged by recent evidence on the capacity of animals to feel pain (O'CALLAGHAN 2002). WHAY et al. (1998a) demonstrate that pain thresholds in normal cattle are similar to those in man. It was in 1994 already when Livingston wrote about the development of pain in animals and their perception of it. He states that the main difference in the perception of pain in man and animals does not seem to be in the generation or perception of the pain, but in the behavioural response. He found that animals feel pain as much and in a similar manner to humans, but they "just don't jump up and down and make such a big fuss about it as we do" (LIVINGSTON 1994).

The rather widespread believe that cattle are relatively insensitive to pain might have come up because cattle mostly show a rather stoical nature, which is actually a survival strat-

egy used by prey species in the wild to divert the attention of a predator away from a sick or injured animal (WHAY 1997; WHAY 1999; O'CALLAGHAN 2002). In addition, lameness is not necessarily confined to a single limb; bi-lateral lameness is relatively common and the counter-balancing effect of two painful limbs can effectively mask the signs of lameness as well (WHAY 1999). Thus, the identification of injury or disease may be difficult until the condition is advanced. Nevertheless, a skilled observer can detect lameness at an early state by observing changes in weight distribution on each of a cow's four legs. So, early recognition of lameness and prompt treatment are possible, even though the cow may not actually be limping because she tolerates a considerable amount of pain (O'CALLAGHAN 2002; O'CALLAGHAN et al. 2003).

There are two reasons why a cow's natural instinct to mask any sign of pain or discomfort is disadvantageous: first, the stockman might not recognize that something is wrong and therefore will not provide any help; second, the animal will continue producing milk as good as possible, even if nothing is done about the lameness. So, not even reduced production will serve as a signal alarming the stockman or farmer (O'CALLAGHAN 2002).

The welfare of a lame cow may be influenced either positively or negatively at three critical stages: during the onset of lameness (before treatment), during the actual treatment, and during the recovery period (O'CALLAGHAN 2002). During the onset of lameness, the most important problem (as mentioned above) is the detection of an animal being lame. During the treatment of a lame cow, inadequate facilities may be used or too low a pain control might be administered, which would mean that often pain control is not given the high priority it deserves (O'CALLAGHAN 2002). Treatment of foot lesions involves physically restraining the affected limb in order to explore the lesion or move away defective horn; both may result in exposing the sensitive corium. Thus, ineffective management of pain during treatment may cause unnecessary suffering. "The most crucial step towards improving welfare and reducing the pain experienced by a lame cow is through prompt, effective treatment" (O'CALLAGHAN 2002). However, few lame cows are treated promptly and often pain is not resolved immediately after treatment. As the majority of lame cows are detected by the farmer or the foot trimmer, the control of pain is restricted to husbandry, foot trimming or the use of orthopaedic blocks. No drugs that could relieve pain are applied if a veterinarian is not consulted (O'CALLAGHAN 2002). Pain and discomfort during the recovery period can be

minimized by providing a clean and comfortable bed (like a straw yard) that allows the cow to stand up and lie down easily. Thus, she may be encouraged to lie for a longer period of time. The cow should only be allowed to walk short distances (e.g. to or from the milking parlour) and should be given easy access to food and water (O'CALLAGHAN 2002).

WEBSTER (2002) believes that the failure to acknowledge the full implications of lameness for cow welfare is shared by farmers, veterinarians and scientists. As pain is an important factor accompanying lameness and decreasing cow welfare, it is necessary to detect pain in an animal at an early stage in order to prevent it from suffering.

6.4.2.2. Assessment of Pain and Discomfort

“The assessment of pain experienced by animals is a crucial aspect of veterinary medicine and animal welfare research” (O'CALLAGHAN et al. 2003). The problem with the recognition of pain in an animal is that there actually are no objective ways of measuring it. Furthermore, the evaluation of pain is rather difficult because it is individual in each animal (PINSENT 1992; O'CALLAGHAN 2002; O'CALLAGHAN et al. 2003). Scientists try to use measurements of biochemical, physiological, pathological and productivity changes in order to assess pain. If used in isolation, each of these parameters may be influenced by factors other than pain (BROOM 1992; O'CALLAGHAN 2002).

The most commonly used indicator of pain or discomfort is behavioural changes. O'CALLAGHAN (2002; similarly O'CALLAGHAN et al. 2003; BROOM 2006) believes that the behaviour of an animal is directly related to how it deals with and survives in its environment. One reason for altering a behavioural pattern may be to avoid pain. In order to be able to recognize any change in the behaviour of a cow, the observer must be aware of the normal behavioural repertoire of the species cattle (O'CALLAGHAN 2002).

O'CALLAGHAN et al. (2003) carried out a study on a herd of 345 lactating dairy cattle, investigating the value of posture scoring during locomotion and of changes in daily activity levels as indicators of pain resulting from lameness. They wanted to demonstrate a way of detecting subtle changes in posture and weight bearing which might relate to pain experienced by the individual animal and which might not be recognized when using locomotion scoring systems designed to detect obvious lameness only.

The posture scoring system they used has already been described in chapter 2.2., and was devised to assess deviations from normal posture adopted by cattle during locomotion. Cows were observed walking past and then away from the observer on a level concrete surface. The behaviours scored were: overall locomotion assessment; spine curvature (the degree of spinal arching); speed (ease/comfort of gait); tracking (hind feet on fore feet positions); head carriage (extent of movement and level of carriage); abduction/adduction (rotation of feet from the direction of travel). Each behaviour category was scored using a five point numerical rating scale: 1 (good/normal); 2 (imperfect); 3 (mildly abnormal); 4 (moderately abnormal); 5 (severely abnormal). Posture scores were validated as indicators of digital pain by comparing foot lesion records against the score before foot trimming. Lameness was defined as two or more postures scoring 3 or above. Daily activity measures were taken by the authors by using pedometers (O'CALLAGHAN et al. 2003).

The authors found strong associations between the scores attributed to cows and the occurrence of foot lesions. Chronic foot lesions were more likely to be associated with higher scores than acute lesions. The authors suggest that either chronic foot lesions cause more pain or that the pain resulting from chronic foot lesions is less easy to hide. In comparison, the severity of foot lesions did not appear to make such a noticeable difference: although severe lesions were usually associated with high scores, some cows with severe foot lesions did not show obvious lameness. The severity of foot lesions had a more pronounced effect on the daily activity levels: lower activity levels were associated with increasing lesion severity, whereas there were no differences between lesion types. In addition, the daily activity measures showed that lameness in general was associated with reduced daily activity levels. Moreover, posture scores and activity levels correlated significantly; the presence of foot lesions was associated with reduced activity levels (O'CALLAGHAN et al. 2003).

These close associations between the observed behavioural parameters and the severity of foot lesions suggest that both the posture scoring system and changes in daily activity can be useful indicators of pain associated with lameness. Such an approach may assist future development of welfare assessment systems (O'CALLAGHAN et al. 2003). In this context it is important for the veterinarian to know that a cow feeling pain can develop a kind of hypersensitivity to further pain and even to mere touching, a state that is termed 'hyperalgesia'.

6.4.2.3. Hyperalgesia

Hyperalgesia is a state that is inseparable from the notion of pain, as pain is usually the starting point for the development of hyperalgesia. LIVINGSTON (1994) found two divisions in the term 'pain', which he called 'physiological pain' and 'pathological pain'. Physiological pain is thereby considered to be the sort of pain which serves as a sensory warning that damage has just occurred; it can be seen as a process which helps an animal survive and may even be termed 'advantageous'. Pathological pain can, by Livingston's definition, arise as a result of some traumatic incident or disease process within the body, and can even occur in the absence of any tissue damage. Physiological pain will often disappear shortly after the stimulus is removed, whereas pathological pain normally continues and even increases even though the damage is constant. Physiological pain is often directly associated with the location of the stimulus, whereas pathological pain is often diffuse or referred to another area.

According to O'CALLAGHAN (2002), two different forms of pain can be distinguished: acute and chronic. Foot lesions due to infection usually cause acute pain, whereas lesions due to horn capsule injuries or mechanical changes within the foot are associated with chronic pain. LIVINGSTON (1994), too, adds the concept of acute and chronic pain to his idea of physiological and pathological pain. He says that when damage first occurs, the pain can generally be classed as acute and physiological. But if damage is allowed to continue, the damaged tissue releases prostaglandin, kinins and other chemicals, which in turn increase the sensitivity of the pain receptors around them, causing an increase in nociception in the area from which the pain is felt. In addition, these chemicals can cause receptors that normally respond to touch to turn into pain receptors. This process, according to Livingston, is called hyperalgesia. WHAY et al. (1997), WHAY et al. (1998a), and O'CALLAGHAN (2002) also found that lameness is associated with an increase in the sensitivity to painful stimuli.

Another process that can take place in the presence of on-going pain is the development of central hypersensitivity. Changes take place within the spinal chord and brain that make the nerve cells more responsive to a given pain signal from the peripheral tissues. The stimulus for these changes is not known, yet this possibly means that a touch may be perceived as pain. Moreover, humans and animals that suffer from chronic pain are more sensitive to acute pain as well (LIVINGSTON 1994; WHAY 1997).

The treatment and the use of analgesic agents have significant effects on the level and duration of hyperalgesia through the modulation of noxious inputs into the spinal chord (O'CALLAGHAN 2002). It is believed that preoperative use of analgesics has a large effect by reducing or eliminating the 'wind-up' mechanism generated by the stimulation of nociceptors (LIVINGSTON 1994; O'CALLAGHAN 2002). WHAY et al. (1998a) studied the duration of lameness and its effect on how long the associated hyperalgesia might last in cattle. They found that lame cattle remained sensitive to noxious stimuli for up to 28 days after treatment. They observed differences between chronic and acute lesions: chronic lesions, such as sole ulcers and white line disease, resulted in a significantly prolonged duration of hyperalgesia, whereas acute lesions, such as digital dermatitis did not. No relationship between the severity of the lesion and the level of hyperalgesia was found. It appeared that any lesion that caused lameness was sufficient to cause hyperalgesia.

The pain perception in the area of the bovine digit is quite complex, mainly because of the insensitive nature of the horny outside layers of the claw, compared to the very high sensitivity of the inner parts of the foot or the interdigital region. Together with the regions of intermediate sensitivity, there is an enormous range of pain perception within a relatively small area. In the majority of cases, a mixture of these sensitivities will be involved (LIVINGSTON 1994). Whatever the range of pain perception may be, the occurrence of its symptom – lameness – can be measured, and veterinarians are able to reduce pain in an animal by applying specific drugs.

6.4.2.4. Veterinary Pain Control

While there is a range of drugs available that can provide adequate analgesia, it is the knowledge of how and why pain occurs which should allow a veterinarian to utilize these drugs to the best advantage. "The bottom line [...] is that, if in our opinion a procedure would be painful if done on us, then as veterinarians it is our duty to provide adequate analgesia to the patient" (LIVINGSTON 1994).

LIVINGSTON (1994) recommends that a veterinarian should look at the range of agents he has available and look at how they work. Then he should consider how pain is produced under different circumstances and try to match the pain to the analgesic for the best effect.

The range of agents that can be considered for analgesia in a case of bovine lameness can be divided into three groups: 1) local anaesthetics; 2) non-steroidal anti-inflammatory drugs; 3) opioids and alpha two adrenergic agonists (LIVINGSTON 1994; WHAY 1997).

Veterinarians have the option to administer local anaesthetics when treating a lame cow. First, this makes treatment easier as the cow tends to stand more quietly; second, it avoids the barrage of stimulation of the nociceptors, which would result in a higher level of hyperalgesia (O'CALLAGHAN 2002). In accordance to the notion of central hyperalgesia, it is most probable that patients suffering from chronic pain will be more sensitive to acute pain; and this acute pain may even be caused by a clinical examination of the area in question. Hence the animal may be more difficult to handle or examine; it may be struggling because the palpation is hurting it and not just because it does not like the examining veterinarian (LIVINGSTON 1994).

The effect of local anaesthetics is supposed to last for about sixty minutes. After this time, sensation gradually returns to the foot and thus pain (O'CALLAGHAN 2002). Therefore, it is advisable to use non-steroidal anti-inflammatory drugs (NSAIDs) in addition to local anaesthetics as it has been shown that the use of NSAIDs modulates the level of hyperalgesia after treatment (LIVINGSTON 1994; WHAY et al. 1998b). The centrally acting drugs are not very popular for use in cattle, but the alpha two agonists, e.g. xylazine, work well for sedation and are potent analgesics as well (LIVINGSTON 1994).

WEBSTER (2002) states that veterinarians commonly pare the damaged feet of lame cows without analgesia. O'CALLAGHAN (2002) carried out a questionnaire survey of cattle veterinary practitioners and cattle foot trimmers in 2001. She investigated the working practices of both groups when dealing with lame cattle and inquired about their perceptions of pain and welfare associated with lameness. 95% of the veterinarians and 83% of the foot trimmers perceived the treatment of lameness to be a potentially painful experience for the cow. Both groups regularly advised the use of straw yard housing following treatment for the benefit of the recovery process and the welfare of the animal. 77% of the veterinarians and 51% of the foot trimmers regularly used orthopaedic foot blocks. As far as analgesic drugs are concerned, only 22% of the veterinarians used local anaesthetics during treatment (mainly for digit amputation or deep excavation of the sole), and only 9% of the veterinarians regularly administered any post-treatment analgesia (e.g. NSAIDs) for cattle lameness. In comparison,

76% of practitioners regularly administer analgesics following the treatment of a lame horse. HEWSON et al. (2007) gained similar results in their study.

FITZPATRICK et al. (2002) asked a group of predominantly veterinary surgeons about their perceptions of pain for a number of common procedures and diseases in cattle. The first question was whether or not it is possible to quantify pain in cattle; 44% thought that it was possible, while 29% did not know. Then the participants were asked if they found a scoring system to quantify pain would be useful in their work; 68% thought it to be useful, although this majority did not agree on whether this would be possible in everyday practice. HUXLEY and WHAY (2006) carried out a questionnaire among cattle practitioners to examine their attitudes and perceptions to pain in cattle. They found that female respondents and more recent graduates tended to give higher pain scores for most conditions, and those who routinely administered analgesics gave higher pain scores than did those who did not.

Several reasons why adequate pain control might not be used in cattle are at hand. Maybe the pain experienced by the cows is simply overlooked out of habit, as the main focus lies on the correction of foot shape and the treatment of lesions. Maybe some people even hope that the animal will make a full recovery without analgesics. Moreover, accepting that a cow is suffering from pain would result in additional time and money to be invested. The behaviour of an animal may be misinterpreted (out of habit again), so the observer believes that the animal is not experiencing any pain, even though a similar condition would be very painful for a human being. Some farmers and even veterinarians believe that pain may actually prevent the animal from moving too much and causing further injury. The ideal and most useful way of controlling pain in this context would be to eliminate the pathological pain while leaving the physiological pain mechanism untouched. But it is almost impossible, with the drugs available, to draw this fine line in animals (LIVINGSTON 1994). If a veterinarian uses local anaesthetics, the effect will only last for a certain time, after which the cow will be severely lame again. It would be in the cow's interest to prescribe longer-acting analgesics for the recovery period as it is highly unlikely that a normal dose of analgesic would block the pain so completely that the cow would cause further damage to the digit (O'CALLAGHAN 2002). With the drugs available, a veterinarian can and should provide reasonable pain management and make things easier, for the animal as well as for himself (LIVINGSTON 1994; LOGUE et al. 1998).

6.4.3. Claw Trimming

Veterinary visits and treatment are one means of preventing lameness and ensure good health and well-being of the cows. Another important factor in the prevention and control of foot lameness in cattle is regular and well-performed claw trimming. The need for claw trimming has long been emphasized (e.g. ANKER 1854); actually, it was at the end of the 19th century that NATHORST (1876) and HESS (1904) stated that cows should preferably be trimmed twice per year, in order to reduce claw-health problems. Associations have been found between insufficient claw trimming and poor foot health (HULTGREN 2002). Regular claw care by claw trimming and footbaths may increase the chances of good hoof-health (VERMUNT and SMART 1994; ALBAN et al. 1995; TIMLETT 2002; CUTLER 2002). Claw trimming can be done by the veterinarian, a claw trimmer or the farmer himself.

Veterinarians usually trim the claws only when they need to during a lameness examination or in order to treat a lame cow by removing defective horn, for example. There is not enough spare time left in a veterinarian's timetable to do regular claw trimming visits on dairy farms, so the job needs to be done by the farmer or a professional claw trimmer. Farmers do not like claw trimming, as SEABROOK and WILKINSON (2000) reported. Their results from a questionnaire survey, in which 238 UK dairy farmers were asked to rate their everyday jobs showed that claw trimming was the second most intensely disliked chore. BORSBERRY et al. (1999) reported that 24 out of 29 farmers questioned performed trimming 'when needed' or once per year, and no farmer reported trimming twice a year or more often.

Regular claw trimming, though, can be beneficial to claw health and animal well-being. MANSKE (2002) studied and described the effects of regular claw trimming on the claw health of dairy cows. He compared two groups of cows, one of which received autumn trimming, whereas the other did not. Both groups were examined at trimming the following spring (four to five months after trimming). Claw trimming in autumn proved to be associated with a significantly positive effect on the prevalence of lameness, and the risk of claw lesions requiring veterinary treatment between scheduled trimmings was reduced in trimmed relative to untrimmed cows.

Routine trimming and corrective trimming are the ways of claw trimming in modern dairy systems (SHEARER and VAN AMSTEL 2001). Under natural conditions, wear balances horn growth, whereas under intensive production conditions wear may be reduced in tie-stall

housing or increased in cubicle systems (BERGSTEN 2001; SHEARER and VAN AMSTEL 2001; MANSKE 2002). Routine trimming is done by correcting the length of the claw and the sole thickness relating to the size of the cow and the underfoot conditions (flooring) in order to maintain a good claw angle and weight distribution in the claws. It can be seen as preventive trimming. Corrective trimming is done on a damaged or diseased claw; loose horn is removed and weight distribution is altered where possible in order to alleviate pain and improve healing and mobility (SHEARER and VAN AMSTEL 2001; TIMLETT 2002; MANSKE 2002). As a minimum requirement claw trimming should be carried out whenever an animal is seen to be lame; better practice may be to carry out routine claw trimmings at times and intervals dependent on the individual herd situation with the aim of maintaining foot balance and preventing excessive horn overgrowth and lameness (CUTLER 2002). From his results, MANSKE (2002) concluded that trimming should be performed at least twice a year; he supposed that the ideal trimming frequency depends on both individual and herd-level factors. The author suggests that in smaller herds (where individual trimming programs are rather impractical) it would be preferable to trim all cows at the onset of the housing period and in February or March if trimming twice per year; and in January and in April if trimming three times per year. With regular claw trimming at frequent intervals, claw lesions will be detected and treated at an early stage (MANSKE 2002), and lameness occurrence can be reduced by 25% (HERNANDEZ et al. 2007).

Periodical claw trimming is one of the three pillars, on which TOUSSAINT RAVEN (1994) bases foot care; the other two are housing and nutrition. The farmer usually does the first two, whereas trimming needs to be done by a trained person. All three pillars have an influence on horn production and horn formation, and even if housing and nutrition are at their best, unsuitable horn formation will still occur to a certain extent. This can be controlled by functional trimming, for instance; a way of trimming based on the knowledge of the pathogenesis of the easily necrotising inflammations of the corium (TOUSSAINT RAVEN 1994).

TOUSSAINT RAVEN (1985) developed the method of 'functional trimming', also called the 'Dutch method' of hoof care. The general guidelines of this method are: give the claw stability and unload the diseased claw by lowering it at the heel. Functional trimming is complemented by curative trimming, which in Toussaint Raven's terms means to thin out any

hard edges of the horn which cause undue and harmful compression on the quick around open defects of the claw, and apply an orthopaedic block under the omolateral sound claw to prevent excessive problems in locomotion. Functional claw trimming aims at preventing claw lesions through maintaining or restoring correct weight bearing within and between the claws and through an improved protection of the solar corium from contusion (TOUSSAINT RAVEN 1994; for further detail see TOUSSAINT RAVEN 1985; TOUSSAINT RAVEN 1989; SHEARER and VAN AMSTEL 2001; MANSKE 2002). A questionnaire carried out by O'CALLAGHAN et al. (2004) showed that 47% of veterinarians and 89% of foot trimmers used the 'Dutch method' regularly.

At the beginning of the 21st century, some authors have examined Toussaint Raven's ideas in terms of claw health and found some critical aspects. On the 12th International Ruminant Lameness Symposium in 2002, PAULUS and NUSS presented a study on the comparison of sole thickness on the medial and lateral hind claws. They found that if the two claws were trimmed to equal size (as it is proposed by Dutch foot trimming), then the sole of the lateral claw was on average 1.6 mm (maximum: 4.1mm) thinner than on the medial. This is not far from exposing the corium. In order to achieve equal sole thickness, the authors recommended leaving the lateral claw larger than the medial. According to the authors, the difference in size is needed not because the pedal bones have different sizes, but because the lateral epicondyle of the metatarsal bone is longer than the medial, producing a difference in weight bearing at the level of the fetlock joint (PAULUS and NUSS 2002). Another two studies by BLOWEY (2002) and by VAN AMSTEL et al. (2002) both discussed the need for a 5 mm step left at the toe (again done in the Dutch foot trimming method). They agreed that such a 'breakover' (rolling over the toe during locomotion, as is often done in horses) is not important in cattle and hence there would be no need for the 5 mm step.

Correctly performed hoof trimming is considered to be beneficial (MANSON and LEAVER 1988b), whereas stress and/or poor trimming technique can be counterproductive (WARD 1999; SHEARER and VAN AMSTEL 2001; MANSKE 2002). For example, the use of a tipping table and older equipment may cause the trimming time to extent to as much as 30 minutes. Modern trimming facilities and electric equipment can permit the procedure to be completed within seven minutes (GREENOUGH 1996). This again means a minimum of distress to the cow. Strict rules are needed for trimming in order to get satisfying results, and

professionals should do the trimming. Learning functional trimming needs supervised training and skilled teachers. Thus, claw trimmers should be enabled to do 90% of the herd prevention treatment (periodic trimming to limit the vulnerable effect of unsuitable horn formation), and veterinarians should learn to treat 90% of individual lame cows (TOUSSAINT RAVEN 1994; similarly WARD 1999). Thus, the two professions can be viewed as complementary to one another in cattle foot care, and can even be complemented by the farmer's knowledge and ideas of a professional nutritionist (TIMLETT 2002; MANSKE 2002).

An increasing amount of routine foot trimming is being carried out by so-called 'paraprofessionals' or 'lay' foot trimmers. In order to maximize the positive impact that a lay foot trimmer can have on the welfare, health and production of the cattle he works on, three key features are needed: competence, communication and cooperation (CUTLER 2002). Gaining and demonstrating competence, however, is not always easy. Certificates of attendance at training courses, obtaining one of the various bovine foot trimming diplomas that exist or membership in a relevant organization such as the National Association of Cattle Foot Trimmers all demonstrate interest and commitment, but not necessarily competence (CUTLER 2002). Cutler suggests that competence may best be judged by watching the individual at work, and assessing the way cows and equipment are handled as well as the depth of understanding the principles of trimming sound and diseased feet. CUTLER (2002), too, pledges the need for communication and cooperation between the farmer, the veterinarian and the foot trimmer. They should discuss those cases where each of them cannot solve the problem alone, so they are able to do the best for the animal concerned. As in other areas of dairy herd management, it is also in claw trimming that a team approach involving dialogue and mutual respect between all interested parties is likely to result in greater animal welfare, cow health, and production benefits for the farmer (CUTLER 2002).

6.4.4. Conclusions on the Role of the Veterinarian and on Claw Trimming

- A cow's environment can be an important factor influencing lameness, so a veterinarian should observe and judge it critically.

- By conducting a herd health service, the veterinarian can provide up-to-date information as well as detect long-term developments, so he can give reasonable recommendations to the farmer.
- Lameness detection and prevention by means of a herd health program influences fertility and productivity in the herd as well, and it results in better economic results for the farmer.
- By giving instructions and information to the farmer, the veterinarian contributes to the farmer's economic success and cattle welfare.
- A thorough examination of a lame cow is necessary to find the source of the lameness.
- A veterinarian has to bear in mind that a lame cow is suffering from some degree of pain, and has to act accordingly.
- Posture scores and daily activity levels can be used by the farmer or veterinarian to assess pain in a cow.
- Pain in a cow can lead to a state called hyperalgesia, which means that the animal is more sensitive to further pain and even mere touching.
- Veterinarians should treat a lame animal by using pain-reducing drugs, so that the animal's well-being is not disturbed by prolonged pain.
- Regular claw trimming should be performed twice or three times a year.
- Thorough education is necessary for correct claw trimming, and modern facilities and tools should be used as this makes trimming easier for both the cow and the trimmer.
- Correct claw trimming can equalize the weight distribution between the claws and thus prevent claw lesions and lameness.

6.5. Genetic Background of Lameness

It is not only the cows' environment that has (been) changed during recent years, cows themselves have been changed genetically in order to increase their productivity – milk yield or feed conversion. For generations dairy cattle have been bred and selected for a number of characteristics, all of which aimed at improving productivity (LOGUE 1997). What has not

been considered in this context is the fact that genes coding for high milk yield do not necessarily code for healthy legs and claws. For economic reasons, genetic selection for animal welfare is neglected in favour of selection for increased milk yield (OLTENACU and ALGERS 2005; similarly VAN DORP et al. 1998).

AMSTUTZ (1987), MCDANIEL (1994) and VERMUNT and GREENOUGH (1995) describe the desired characteristics of a cow's feet: the conformation of the cow's foot should be short, steeply angled, high in the heel, and evenly clawed. The sole should be somewhat concave. The most common claw traits were discussed by the EAAP Working Group 'Claw Quality in Cattle' (POLITIEK et al. 1986; DISTL et al. 1990): these traits consisted of an evaluation of the claw shape, the quality of the claw horn and features of the inner structure of the claw. As was demonstrated by several studies, these traits had sufficiently high additive genetic variation to achieve genetic improvement. Claw measurements are significantly correlated genetically and phenotypically to the prevalence of claw disease, longevity and lifetime performance (GREENOUGH 1996). So, most lameness could be prevented if proper attention was paid to selecting breeding animals with correct foot and leg conformation; in other words, any animal with a serious genetic defect of the feet should not be used for breeding purposes (AMSTUTZ 1987).

DISTL (1990) showed a genetic component of lameness and of foot and leg shape in German Simmentals. BOETTCHER et al. (1998) describe highly significant correlations between lameness and phenotype traits such as foot angle, rear legs and rump width, as do van der WAAIJ et al. (2005). Also, overly straight hocks, splay toes, or overlapping toes are commonly seen with an increase in the rate of lameness. The heritability of lameness ranks from 0.14 to 0.22 (MCDANIEL 1994; VAN DER WAAIJ et al. 2005); PRYCE et al. (1998) report the heritability of lameness to be 0.015 to 0.005 only, whereas VAN DORP et al. (1998) found the heritability of lameness to be 0.16. Several claw disorders seem to have a partially genetic basis; the heritability of heel horn erosions is set to be between 0.13 and 0.15, that of interdigital dermatitis to be 0.13, of sole ulcer to be 0.39, and of white line disease to be 0.17 (MCDANIEL 1994). The total number of lesions observed on the feet of Friesian cows is reported to be 0.39 (SMIT et al. 1986; CALAVAS et al. 1996).

The heritability of lameness seems to be influenced by other factors associated with a cow's body traits as well, like breed, body weight, claw horn colour, and milk yield. In a Dan-

ish study carried out by ALBAN (1995), the author found that the Danish Jersey breed had a lower risk of lameness than did the Red Danish, the Danish Black and White and the Danish Red and White, as the latter breeds are all heavy breeds, while Danish Jersey is a light breed. ENEVOLDSEN and GROEHN (1991) found that body weight was positively associated with sole ulcer. Claw horn colour seems to be associated with the occurrence of lameness as well, as white claws seem to be more susceptible to lameness than are black ones (CHESTERTON 1989). Selection for high milk yield tends to increase lameness (WARD 2001); large breeds have a high milk yield, which might predispose them to lameness (ALBAN 1995).

In recent years, not only bulls have shown to be a possible risk factor (WARD 1999) in passing their possibly defective genes onto their progeny. With embryo transfer becoming more and more popular, so that hundreds of calves can stem from only one cow, the cow too is recognised as a possible threat to the integrity of the genetic pool (AMSTUTZ 1987). Nevertheless, breeding organizations now publish the shape of feet and legs in bulls, which should help reduce the risk of lameness; it was in 1987 already that Russell showed that the daughters of some bulls were much more likely to suffer from foot lameness than those of other sires. Managers of dairy herds with a high prevalence of lameness should be encouraged to consider selection of bulls, which sire shorter, steeper claws in addition to high milk yield (VERMUNT and GREENOUGH 1995).

Genetic selection of certain traits seems to be a practical way of improving locomotion in dairy cattle (MCDANIEL 1994; BOETTCHER et al. 1998). DISTL (1994) believes that genetic improvement of claw and leg conformation should enable animals to resist influences of the environment without suffering from diseases or reducing their performance ability. The author proposes a certain guideline as to what should be considered when defining the genetic traits to be preferred. He suggests that claw and leg traits for breeding objectives should be carefully defined and the traits chosen should be tested for their usefulness in practical breeding work and in respect to the environment the animals are exposed to. Possible other side effects on the musculoskeletal or other system should be avoided. Traits to be used in breeding work should consequently be related to susceptibility for claw and leg diseases on the one hand, and to management requirements such as low need for claw care and to functional aspects of locomotion on the other hand.

This implies that the traits necessary seem to be of a complex nature and seem to depend on and respond to the exposure to environmental effects (DISTL 1994). Phenotypic traits to be used in genetic improvement of claw and leg characteristics should contribute to the decrease of the lameness problem in the future. As the most common cause of lameness is located in the claw, more selection pressure should be put on claw traits. Nonetheless, according to DISTL (1994), WEBSTER (1995) and BOETTCHER et al. (1998), target traits for claw and leg quality should be defined carefully. They should include the incidence of all relevant claw and leg diseases and of correlated diseases as well as production traits that are related to claw and leg quality.

There are a number of consequent challenges to breeders and geneticists. It will be important to maintain the fitness of very high producing animals by recording health, fertility, longevity and parlour traits and to use these data to give them appropriate weight in selection decisions (HILL et al. 1995; similarly VAN DORP et al. 1998). The ultimate goal in breeding programs for dairy cattle should be to produce animals with a high yield and high claw quality (VERMUNT and GREENOUGH 1995); thus, the longevity and lifetime performance of the animals could both be improved (DISTL 1994), and the quality of dairy cow life could be enhanced (OLTENACU and ALGERS 2005).

6.5.1. Conclusions for Genetic Background of Lameness

- Breeding programs for healthy feet should be encouraged.
- Animals with correct claw and leg angles need to be selected for breeding.
- Bulls should be considered in terms of giving their genes to their progeny; cows are important, too, especially with modern techniques like embryo transfer on the rise.
- Claw and leg traits for breeding objectives should be carefully defined.
- The traits chosen should be tested for their usefulness in practical breeding work and according to the environment the animals are exposed to.
- Possible side effects on the musculoskeletal or other system should be avoided.
- Traits to be used in breeding work should consequently be related to susceptibility for claw and leg diseases on the one hand, and to management requirements such

as low need for claw care and to functional aspects of locomotion on the other hand.

- As the most common cause of lameness is located in the claw, more selection pressure should be put on claw traits.

7. Risk Assessment of Factors Influencing Lameness

It was in 1997 already that the Farm Animal Welfare Council wrote in its Report on the Welfare of Dairy Cattle: “[...] we found the prevalence of lameness to be at an unacceptable level. Lameness is an extremely painful condition and steps must be taken, as a matter of urgency, to reduce the incidence”. Prevention of ruminant disease seems to be the modern approach to this increasingly recognized and economically significant problem. Successful cattle breeders and farmers are no longer interested in successful treatment of a lame animal only. They want to know why the animal became lame and what they can do to prevent the occurrence of further lameness.

Dairy farmers and cattle breeders are obviously no longer satisfied with controlling the ‘end product’ of their production system, which is the cow, her health and productivity. They do not want to take measures on the problem ‘lameness’ when it already has occurred, but are interested in controlling the process factors that (can) lead to the occurrence of lameness. Thus, they would be able to minimize or even eliminate certain factors triggering the occurrence of lameness, and could already take measures during the process to decrease the risk of the animals becoming lame. In consequence, such process controlling would decrease the number of cows suffering from lameness as it had been prevented earlier.

In order to design a proper assessment of the factors influencing lameness, one option is to make use of the principles of the so-called HACCP-concept (see below). Therefore, it is necessary at the outset to define the terms ‘risk’ and ‘hazard’, to explain about HACCP and its basic steps, and to adapt certain aspects of the concept to the subjects of dairy cow lameness and cattle welfare, before a risk assessment of factors influencing lameness can be generated.

7.1. The HACCP Concept

A system aiming at controlling the production process rather than the end product has already been established in the food industry. Quality management and the control of specifically determined critical points have been systematised in a concept called **Hazard Analysis and Critical Control Point (HACCP)**. This system was developed by the U.S. Army Natick Research and Development Laboratories and the National Aeronautic and Space Administration (NASA) to be able to produce safe food for astronauts. It was designed to identify, assess and control specific health hazards inherent in food (NOEHLE et al. 2004).

The HACCP concept is based on seven steps, which are (NOORDHUIZEN et al. 1997; NOEHLE et al. 2004):

1. Analysing hazard.
2. Defining Critical Control Points (CCPs).
3. Defining one or more critical limits for the CCPs.
4. Establishing a monitoring system for the CCPs.
5. Defining corrective actions to be used if the monitoring system marks a CCP as not being under control.
6. Applying verification methods and tests to prove the HACCP plan to be working effectively.
7. Using a system documenting all procedures and data.

In food risk assessment terminology (NOEHLE et al. 2004), *hazard analysis*, (the first step of a HACCP), comprises two aspects, *hazard identification* and *risk assessment*. A *hazard* is defined as a biological, chemical or physical agent in food, or condition of food, that has the potential to cause an adverse health effect. *Risk* is defined as a function of the probability of an adverse health effect and the severity of that effect as a consequence of a hazard in the food. A *risk assessment* is supposed to be a systematic and scientifically based process that serves to judge *hazard characterisation* and *exposure assessment* by way of summarising; it includes the four steps *hazard identification*, *hazard characterisation*, *exposure assessment*, and *risk characterisation*.

Hazard identification, in food risk assessment terminology (NOEHLE et al. 2004), is the determination of known or potential adverse effects caused by an agent. *Hazard characterisation* is used to describe the connection between the agent's amount and the severity of the adverse effect, bearing in mind the triangle between human being, agent and the food carrying the agent. *Exposure assessment* aims at tracing the agent on its way through production and determining its amount when the food is consumed. In the *risk characterisation*, information from the other three steps is combined in order to determine chance and severity of adverse effects or disease for each hazard under different exposition conditions. Thus, a risk characterisation is to put the acceptable risk in concrete terms, so that scores can be defined including a cut-off between 'unacceptable' and 'still acceptable'.

In order to be able to make use of this system for the dairy cow industry with respect to cattle lameness and dairy cow welfare, it is necessary to adapt the above definitions and explanations to the terminology of dairy cow lameness and welfare.

7.2. Adapting HACCP to Dairy Cow Lameness and Welfare

While in the 1980-ies and 1990-ies programs of herd health and production management were predominant, the on-farm decision-making process can be supported by focusing on data analysis and qualitative advice, risk analysis and quantitative epidemiology. They are supposed to give insight into the outcomes of a production process and to focus on prospective action. Since product quality and product acceptance are determined by both the quality of the product and the quality of the production method, these two were compromised in a systematic control program, the HACCP (NOORDHUIZEN et al. 1997).

Whereas HACCP has become an established part of the food industry during recent years (NOEHLE et al. 2004), its integration into animal production systems is still in its infancy. On the one hand, factors in animal production are not as controllable as they are in industrial production, because the animal as a sentient being is not measurable, determinable and controllable as are machines. On the other hand, some of the basic definitions of HACCP do not fit animal production, and maybe even some of the seven HACCP-steps will need revising to adapt them to animal production. Moreover, the quality of an industrial or food product during the production process and especially at the end of it is far easier to assess than lameness

occurrence and the quality of animal welfare. This is due to the fact that quality standards and assessment factors of industrial and food products can be objectively and scientifically determined and measured, whereas cattle lameness and welfare cannot; at least they have not yet been successfully defined or even made assessable.

While the basic steps of the HACCP concept seem to be useful for a hazard analysis of dairy cow lameness and animal welfare as they are for the time being, the terms *hazard* and *risk* need to be somewhat modified to meet cow production and welfare features, as do the definitions of *hazard identification*, *hazard characterisation*, *exposure assessment*, and *risk characterisation*.

A *hazard for the occurrence of lameness and decreased welfare in dairy cow production* can be defined as an environmental, mechanical, nutritional, physiological, genetic, microbiological or human feature or agent, that has the potential to cause lameness and an adverse effect on animal welfare. A *risk* can then be defined as the probability of the occurrence of lameness and of an adverse effect on animal welfare, combined with the severity of lameness and decreased welfare as consequences of given hazards.

Besides adapting the definition of the terms *hazard* and *risk*, it is also necessary to adapt the explanations of the four steps of a risk assessment to the terminology of dairy cow lameness and cattle welfare. *Hazard identification* should be defined as the determination of known or potential factors and features in a cow's surroundings causing adverse effects on locomotion and welfare. *Hazard characterisation* is used to describe the connection between the factors' or features' presence or expression, and the severity of its adverse effect, bearing in mind the triangle between animal being, factor/feature and the whole surrounding system of dairy farming. The *exposure assessment* aims at trailing the factors/features on their way through the productive life of a cow, and determining their height of expression when lameness occurs. In the *risk characterisation*, information from the other three steps is combined in order to determine the chance and severity of lameness and adverse effects on welfare for each hazard under different exposition conditions. Thus, the acceptable risk is supposed to be put in concrete terms, so that scores could be defined including a cut-off between 'unacceptable' and 'still acceptable'.

With these definitions at hand, a risk assessment of factors influencing dairy cow lameness can be attempted.

7.3. Dairy Cow Lameness: Risk Factor Assessment

A *risk assessment*, by definition (NOEHLE et al. 2004), is supposed to be a systematic and scientifically based process that serves to judge *hazard characterisation* and *exposure assessment* by way of summarising, and includes the four steps *hazard identification*, *hazard characterisation*, *exposure assessment*, and *risk characterisation*. This *risk assessment* here is meant to be a risk assessment of factors influencing the occurrence of lameness in dairy cows and thereby decreasing cow welfare.

7.3.1. The Four Steps of a Risk Assessment

Step one is to *identify the hazards* of this condition. This can be done by summing up chapter 6 of this study: risk factors for the occurrence of lameness in dairy cows are found in the type of housing, the kind of flooring, the level of hygiene and the amount of daily exercise, nutritional concepts, management and stockmanship, veterinary care and pain control, claw trimming, and genetics.

As far as *housing* is concerned, risk factors are:

- Tie-stalls; they reduce any free movement of cows.
- Too short tie-stalls; they make the animal stand for longer periods of time (instead of lying down) or make it stand with its hind feet in the gutter.
- Too low a number of cubicles in a cubicle housing; they should be at least the same as the number of cows stabled.
- Uncomfortable lying places for the cows; cubicle size should be chosen according to a cow's need of space.
- Excessive standing and walking on uncomfortable floors.
- No accommodation to a different floor surface; this is true especially when cows are changed from soft to hard floors.
- No soft bedding in the stalls.
- Concrete flooring.
- No soft surface areas in traditional concrete flooring systems.
- Rubber flooring without additional soft bedding.

- Improper floor hygiene, wetness and faecal contamination of the floor.
- No regular exercise.
- Wet and rough surface of the exercise area.

As far as *nutrition* is concerned, risk factors are:

- No thorough design of dairy cattle diets.
- Diets that do not meet the individual demands of the cow for fibre and energy, according to her stage of lactation and physiological demands.
- A too low fibre content out of forage in the diet.
- Energy density too high or too low.
- Bad food quality.
- Rations that induce ruminal acidosis and laminitis.
- Fast changes in ration composition.
- Too low particle size in the ration.
- Using the same total mixed ration for different groups of cows.

As far as *management and stockmanship* are concerned, risk factors are:

- Herd size exceeding a manageable level for the stockpersons.
- Herd size is not chosen according to the stall space available.
- Not enough stalls are provided, i.e. less than one for each cow.
- Stockpersons do not handle cows in a consistent, responsible and sensible way.
- Stockpersons make cows hurry along their track or treat them mean.
- Delayed detection of health problems, e.g. lameness.
- Stockpersons are not trained at identifying lame cows at an early stage.
- Stockpersons do not improve their knowledge about lameness, handling facilities and methods to treat a lame cow correctly.
- Stockpersons do not record the lameness status of each cow regularly.
- Behavioural alterations (way of standing or walking, time spent lying etc.) are not taken into consideration in deciding if a cow is lame or is going to be lame.

- The dairy herd does not have a routine lameness scoring program that fits the needs of the herd (problems) concerned.
- Records of regular lameness scoring procedures are not taken.
- The lameness scoring system used does not contain specific terms and detailed definitions of each of the scores to make scoring as objective as possible.
- Lameness scoring is used neither for detecting lame animals, nor for detecting animals showing changes in gait and/or behaviour, before they become clinically lame.

As far as *veterinary care and claw trimming* are concerned, risk factors are:

- The veterinarian does not take a cow's environment into consideration.
- The veterinarian does not provide a herd health service, and cannot or does not give reasonable and sensible recommendations to the farmer.
- A lame cow is not thoroughly examined.
- A veterinarian does not bear in mind that a lame cow is suffering from some degree of pain, and does not act accordingly.
- The veterinarian does not consider that pain in a cow can lead to a state called hyperalgesia, which means that the animal is more sensitive to further pain and even to mere touching.
- The veterinarian does not treat a lame animal by using pain-reducing drugs, so that the animal's well-being is disturbed by prolonged pain.
- Regular claw trimming is not performed twice or three times a year.
- Claw trimming is not done by a thoroughly educated person.
- No modern facilities and tools are used for trimming.
- The weight distribution between the claws is not equalised by correct claw trimming.

As far as the *genetic background of lameness* is concerned, risk factors are:

- Breeding programs for healthy feet are not used.

- It is not animals with correct claw and leg angles that are selected for breeding.
- Bulls are not considered in terms of giving their (possibly defective) genes to their progeny.
- Cows are not considered in terms of giving their (possibly defective) genes to their progeny, either; this is important with modern techniques like embryo transfer on the rise.
- Claw and leg traits for breeding objectives are not carefully defined.
- The traits chosen are not tested for their usefulness in practical breeding work and according to the environment the animals are exposed to.
- Possible side effects on the musculoskeletal or other systems are not taken into consideration or tried to be avoided.
- Traits to be used in breeding work are not consequently related to susceptibility for claw and leg diseases on the one hand, and to management requirements such as low need for claw care and to functional aspects of locomotion on the other hand.
- Not enough selection pressure is put on claw traits.

This list of features and factors that can be found in a dairy cow's environment and which are identified as hazards does not give detailed descriptions of the hazards listed. This desired *second step* of the risk assessment, the *hazard characterisation*, has already been carried out in chapter 6, where potential risk factors and features have been described in detail, and have been linked to the cow as a sentient animal as well as to the whole system of dairy farming. Yet, it is not possible to describe the connection between the presence or expression and the severity of adverse effects for each factor or feature in isolation, as they always co-exist. In addition, the studies reviewed in this study are not consistent in their approaches and aims, which makes comparison difficult if not impossible; some studies focus on lameness, whereas others concentrate on lesions, and some of them even mix lameness and lesions without clarifying the conceptual situation.

Step three, exposure assessment, is supposed to aim at tracing the factors and features on their way through the productive life of a cow, and determining their height of expression

when lameness occurs. This presents itself as a rather ambivalent step for several reasons. Basically, each dairy cow is exposed to one or more potential risk factors for lameness during her life, because it is system-inherent that a dairy cow is not exposed to one risk factor at a time, but to several risk factors simultaneously during her productive lifetime. Even if all factors affecting the cow were optimal, there still remains a cow-inherent risk of lameness and decreased welfare for the cow as she is an individual 'feeling good' about some things and 'bad' about others, and exhibiting an individual quality of looking after herself or being likely to hurt herself.

As long as the single factors that can contribute to lameness occurrence are considered in isolation, they can theoretically be judged as to whether each of them has an influence on the occurrence of lameness or not. To look at and judge a combination of factors – because this is the way they usually are found on each farm – is not that easy as every farm is different in design and comprises a different combination of risk factors. Theoretically, each potential risk factor could be given a specific risk score, so that factor risk scores could simply be summed up according to their combinational presence on a farm. This, however, is rather difficult, as the score of each single factor is inseparable of the coexistence with other factors given on a farm. For example, on farm A factor X may need to get a lower score as on farm B, because on farm A factor Y is present that decreases the risk adherent to factor X, whereas on farm B factor Y is not present. It becomes obvious that all factors influencing lameness are set in relative positions to one another, and cannot be attributed straight and absolute positions and scores.

This relativity is further enlarged by taking into account that the farmer and stockpersons are of great importance in the cows' surrounding as well. As humans, they cannot each be attributed the same features, and thus cannot be scored evenly. Even if two farmers had the same education and had gained the same knowledge on dairy farming, it still remained a matter of personality how they use their knowledge and handle their cows. One last factor contributing to the problem of ambivalence and relativity is the fact that all studies reviewed here on the subject of which factor influences lameness to what extent are non-uniform, if not to say inconsistent, in the methods used as well as in their research aims and definitions. Some authors examine how housing influences lying behaviour and thereby lameness, others com-

pare the occurrence of claw lesions on different floorings, whereas others investigate what kind of lameness is connected with what kind of lesion.

Resuming these thoughts on hazard characterisation and exposure assessment, two things can be concluded: first, in order to gain data on certain lameness risk factors to be used in a risk assessment, consistent – or at least comparable – methods and approaches for studies on this subject are needed, but are not available so far. Additionally, terms used should be defined consistently, too, and a clear distinction needs to be made whether the studies focus on lameness or lesions. And second: as long as these prerequisites are not given, any risk assessment of factors influencing lameness has to remain an estimation, as no scientifically and uniformly based data are at hand.

Reconsidering the initial definition of a risk assessment as a systematic and scientifically based process, this study's attempt in developing a scientifically based risk assessment of factors influencing dairy cow lameness has failed due to the unscientifically performed hazard characterisations and exposure assessments found in the published literature until today. Nonetheless, and bearing this fact in mind, it can be worth while combining the information from the other three steps and a kind of *risk characterisation (step four) in a risk assessment*, which, in the context developed so far, can also be considered a *practical approach to a risk assessment*. Yet, the risk characterisation cannot result in determining the chance and severity of lameness and adverse effects on welfare for each hazard under different exposition conditions, because of the reasons already mentioned and the inseparable connection of risk factors and features for lameness. Thus, the acceptable risk – that is supposed to be put in concrete terms – can only be put in relative terms, if at all (considering the combinative nature of the risk factors and the inconsistent scientific approaches), and scores cannot be provided. This task has to be left open for further scientific studies, and future research should try to define scores as well as point out a relative or even distinct cut-off between 'unacceptable' and 'still acceptable'.

7.3.2. A Practical Approach to a Risk Assessment of Factors Influencing Dairy Cow Lameness and Welfare

Even though the development of a scientifically based risk assessment of the factors influencing dairy cow lameness and welfare has failed, the results and insights into the problem of lameness in cattle gained from this study's literature review and from the attempt to integrate these ideas into a risk assessment scheme based on HACCP principles can be used to develop some thoughts on what is hazardous for dairy cows and their well-being as well as on what may be helpful to improve the welfare of dairy cows in practical terms.

The food-industry-HACCP is supposed to be strongly prevention-oriented (NOORDHUIZEN et al. 1997), and so should be any assessment and control program for dairy cow lameness and welfare. NOORDHUIZEN et al. (1997) believe that HACCP on dairy farms should be specially focused on active participation of the farmer in the production process and through this in controlling product quality. With respect to this, any assessment and any control system on a dairy farm should be focused on the farmer as the responsible person.

Yet, there is another aspect that puts the *farmer* into the centre of assessments and control systems for dairy cow lameness and welfare. The farmer is the one element among all factors and features surrounding the cow that can act and decide of his own accord. He is the one to make decisions on the housing system, flooring and hygienic concepts, he designs food rations for the animals and handles them, he needs to decide when to call a veterinarian and a claw trimmer, and he chooses the sires and cows for breeding. All this depends on his knowledge and training, and on his willingness to take over the responsibility to decide in his cows' interest. The farmer is the one 'factor' that can influence all the other factors, and that can make the cows' material surroundings good or bad, welfare-threatening or not, a risk factor for lameness or not.

Thus, the *farmer* is considered the most important factor influencing lameness in this unscientific risk assessment; this applies to the stockpersons as well. Although the farmer has to take economic impacts of his decisions into account, he still is the one to decide on the well-being of his animals. Among the other factors influencing lameness, no linear ranking can be designed for the reasons mentioned above. Nonetheless, *bedding* and *hygiene* can be considered of considerable importance in the development of lameness in cattle. *Soft bedding* is beneficial for the cows' claws, as several studies worked out, and encourages the cows to lie down for longer times, which again increases claw health and, in addition, cow comfort. Soft

bedding shields the claws from unphysiological loads and wear, and thus eliminates some risk factors for specific claw diseases, and contributes to cattle welfare. *Hygiene* is important in this context, too, as a soft bedding that is cleaned and renewed regularly in short intervals is more claw-protective than soft bedding that is seldom renewed. Even in terms of cow-unsuitable flooring, like concrete, hygiene is important. Clean concrete flooring is still better than wet and dirty concrete flooring, though avoiding concrete as flooring would be the best.

Another factor that is equally important as bedding and hygiene is the *stall size* and the possibility of *free movement* for the cows. A stall of whatever kind (except for tie-stalls that are considered inadequate for cows due to their limitation of movement of any kind) should provide enough space for each cow to lie down and get up, to feed and drink and to move around easily and to an extent she likes. This means either building a large enough stable for a given number of cows, or keeping only as many animals as the stable size given allows for.

Nutrition can be considered another important factor, and it is not easy to rank it in comparison with the other factors. The best nutrition will do cows no good if stall size, bedding and hygiene are poor, and vice versa. Nonetheless, it is essential to design rations high in fibre and high enough in energy for the cows, according to their nutritional and physiological demands, and to use food of good quality only.

Quality with respect to claw and leg traits and to productivity should be desired when selecting bulls and cows for *breeding* purposes. As lameness and the susceptibility for certain claw diseases seem to have a genetic component, thorough selection of phenotype traits can help in reducing the risk for animals to become lame. Again, this factor cannot be judged without considering the remaining factors, because although a cow may have a certain genetic determination of not becoming lame that easily, phenotype traits are always influenced by environmental conditions in their expression. So, genetic selection can only be as good as the environment the genetic traits will be exposed to.

Besides deciding with which animals to breed, the farmer also has to decide when to consult a *veterinarian*. The sooner he does it in cases he himself cannot cope with the lameness of a cow, and the sooner in the onset of lameness he realises this, the fewer lameness problems he will have and the less will the cow have to suffer from pain, and the better the well-being of the cows will be. This is similar for *claw trimming*, as regular claw trimming by a well-trained claw trimmer can help prevent lameness and can increase dairy cow welfare. This fac-

tor, again, is only one out of a considerable number of factors, and can only be as good as the other factors' statuses allow it to.

Reviewing these thoughts, all the factors and ideas mentioned seem to be common sense. With companion animals, all these things seem to be more natural and are usually done more or less without thinking. Companion animals may have the advantage of being viewed more as a family member than the average farm animal. Nevertheless, farm animals deserve the same rights as companion animals, and basic husbandry factors should be applied to farm animals in a similar way as they are for companion animals. Dairy cows are an important economic factor for a farmer, and therefore, it is in his own interest to create the best surroundings possible for his cows out of the circumstances given on his farm. Thus, he will be able to achieve economic profit on the long term, and will prevent his cows from lameness, suffering and bad welfare.

8. Conclusions

By reviewing literature on the subject of dairy cow lameness and attempting to develop a risk assessment on the same subject, this study has identified and characterised the important factors influencing lameness.

The following conclusions can be drawn:

1. Lameness in dairy cows is a worldwide problem in intensive farming systems.
2. Lameness results in economic losses for the dairy farmer.
3. Lameness is a painful condition that leads to poor welfare for the cows.
4. Lameness is a complex issue, and its occurrence is influenced by a number of co-existing factors, like the type of housing, the kind of flooring, the amount of hygiene and daily exercise, nutritional concepts, management and stockmanship, veterinary care and pain control, claw trimming, and genetics.
5. These factors influencing lameness cannot be assessed in isolation.
6. There is an ongoing discussion among scientists about a consistent definition of the term 'welfare'.
7. An objective assessment of cattle welfare has not been established.
8. A working dairy cow lameness and welfare risk assessment has not been designed yet.
9. The food industry HACCP concept can be used as a basis for a risk assessment of dairy cow lameness and welfare.

10. A practical approach to a risk assessment of factors influencing dairy cow lameness and welfare was carried out.
11. The terms *hazard* and *risk* as the two central terms of the HACCP concept were adapted to dairy cow lameness and welfare, and are now applicable to a dairy cattle HACCP plan.
12. The four steps of a HACCP-based risk assessment (hazard identification, hazard characterisation, exposure assessment and risk characterisation) have been adapted to dairy cow lameness and welfare and thus made applicable in this context.
13. *Hazard identification* and *hazard characterisation* (the first two elements of a risk assessment) were conducted by using the information on factors influencing the occurrence of cattle lameness gained in chapter 6.
14. Thus, a list of risk factors for dairy cow lameness was generated and is now available.
15. The data collected so far proved to be too impractical to be used in a scientifically based risk assessment, as definitions and approaches of the studies reviewed are not consistent, and thus comparison was not possible.
16. The farmer was evaluated to be the most important risk factor for dairy cow lameness as he is the only factor that can act of his own accord and can decide on every other influence factor.
17. No risk assessment is available that can assess single factors as well as a combination of factors.
18. A system of controlling lameness by managing and controlling the co-existing factors is lacking.

19. Consistent definitions and approaches to modify the food industry HACCP concept and make it completely applicable to the assessment and control of dairy cow lameness and welfare are lacking.
20. Information gained from the *hazard identification* and the *hazard characterisation* carried out in this study can serve as a basis for future risk assessment and control programs.

9. Future Considerations

Bearing in mind the Farm Animal Welfare Council's 1997 Report on the Welfare of Dairy Cattle, and the fact that successful cattle breeders and farmers want to know about factors influencing the occurrence of lameness and their prevention, some considerations for the future need to be made to meet these demands. On the one hand, there are still several subjects of dairy cow lameness and welfare that are worthwhile being scientifically studied. On the other hand, practical implementations for the dairy farmer can already be drawn from this literature review and the practical approach to a first step risk assessment.

9.1. Further Research and Recommendations

Nearly every issue dealt with in this study has shown the need for further research. Besides probably valuable new research results that could be gained from rethinking the subject of dairy cow lameness and welfare, another valuable goal to be achieved by reconsideration would be a change in people's respectively farmers' attitudes towards farm animals, their needs and well-being. It was in 1989 already when BROOM demanded a change in people's attitudes towards animals. He wanted to gradually provide information on animal welfare and educate children in a sensible way. In order to obtain the information needed to bring about a change in attitude, BROOM (1989) wanted to investigate the welfare of animals and to make people consider every individual and every animal in a compassionate way.

The past and the current discussion about animal welfare and its implications shows the need for a scientifically useful and consistent definition of the term 'welfare', as well as for transparent explanations of ethical assumptions, and for objective methods to assess the welfare of livestock in different environments. Moreover, a scientifically useful concept of welfare is needed that can be scientifically assessed and that includes the notion of animal feelings. This task, however, will not only take time, but will require the trusting, loyal and fruitful cooperation of the various disciplines involved in dairy farming. This gives room for further interdisciplinary discussion and research.

As far as 'cow comfort' is concerned, an assessment of thoroughly defined behavioural alterations should be designed in order to detect diseases and lameness at an early stage, and to complement lameness scoring systems. Each alteration of thoroughly defined normal behaviour should be given a score that expresses its effect on cow comfort. Thus, reverse conclusions on cow comfort could be drawn. In this context, further research on a cow's lying and standing behaviour could be performed, too, to gain a better understanding of behavioural alterations. In addition, close associations between behavioural parameters of a cow and the severity of foot lesions suggest that both the posture scoring system and changes in daily activity may be useful indicators of pain associated with lameness. Such an approach may assist future development of welfare assessment systems (O'CALLAGHAN et al. 2003).

A lot of lameness and gait scoring systems have been developed so far, and have been used on farms and for research studies. Recently, some automated methods to detect lameness have been studied (load distribution, pedometers); yet, they need to be refined in terms of reliability and practicability under on-farm conditions. As far as the 'traditional' scoring systems conducted by man are concerned, it would be useful to develop a scoring system that takes single gait attributes into account. Scores would thus become more detailed, and chances of detecting lame animals even at an early stage, would become greater. Therefore, research should determine which gait attributes are necessarily needed in a composite scoring systems. For this, individual effects of claw pathologies on gait need to be identified. Furthermore, research should evaluate how subjective assessments work when compared with more objective methods of assessing gait in dairy cattle. This seems to be necessary as in an on-farm situation the more 'traditional' methods will still be mostly used because technical equipment (such as cameras or scale-platforms) will not be available.

Further research on different flooring types would be beneficial in terms of cow comfort and welfare. Different rubber flooring systems should be studied in greater detail and with respect to bedding, too. In addition, the design of soft areas to make a given concrete flooring more attractive and comfortable for cows could be tried.

Concerning nutrition, efforts should be made to improve digestibility of dietary components (thereby increasing feed efficiency) and to optimise ruminal fermentation. Further studies could concentrate on the improved use of nitrogen and phosphorus for the animal's benefit, and on the reduction of contaminating the environment. Further detailed research into the understanding of the nutritional requirements of cows is important (EASTRIDGE 2006). Accurate physiological diagnostic tests should be developed that can alert managers to subclinical acidosis and laminitis in a herd. Effects of subclinical lameness on cow welfare should be investigated.

Stockmanship research should focus on the optimal way for a stockperson to watch and handle groups, for example through better knowledge of the group itself and/or through the control of certain key individuals. More knowledge is required concerning the way animals integrate humans into their perceptual world. In addition, the relationship between a farmer's training and the health of his cattle deserves further research (MILL and WARD 1994).

The veterinarians' education is another field for further research. If the bovine practitioner is to make a positive contribution to cattle welfare, he needs to have a clear understanding of what constitutes welfare as perceived by the cow, and where the main problems are likely to arise. In addition, the veterinarian should be able to propose mechanisms for definition and comprehensive analysis of welfare problems and to suggest some approaches to their control (WEBSTER 1997). As far as a veterinarian's practical work is concerned, research is needed on refining examination strategies in lameness examination in cattle (similar to those in horses). Some methods used in examining lame horses could be adapted to the examination methods usually applied to cows, like the Obel-grades. Another important factor in veterinary education is pain management in cattle. More research should be done on how to teach future veterinarians about pain in cattle and hyperalgesia, and their consequences for the treatment and handling of a cow. Finally, veterinary education and the transfer of knowledge to dairy farmers need to keep up with the excellent information that has been made available from research over the past few years (GREENOUGH 1996). As far as the examination of cows

and claw trimming are concerned, research on improved methods of cow support and restraint facilities is needed (BLOWEY 1998).

Concerning genetics, research that examines all of the genetic factors that contribute to economic losses from problems with feet and legs is warranted (BOETTCHER et al. 1998). Another profitable direction for future studies is to design guidelines for the genetic selection of dairy cattle in order to increase resistance to digital disease, and to improve longevity. The dairy industry is still relatively unaware of the considerable importance of claw size, shape and quality, so improvement is necessary.

Placing the emphasis on disease risk management instead of disease control, the main focus lies on prevention rather than on curative actions. NOORDHUIZEN and WENTINK (2001) believe that thereby cattle management would be more cost-effective. The authors take the concept of preventive medicine programs and herd health plans a step further by looking at recent developments in herd health programs on dairy farms. The authors emphasize the need to merge herd health programs with quantitative epidemiological methods and principles; they stress the importance of integrating veterinary herd health programs and quality (risk) management support at a dairy farm level (as NOORDHUIZEN et al. already did in 1997 when they thought about making use of the HACCP system on dairy farms). WHAY and MAIN (2004) want to transfer the HACCP-concept onto the dairy industry as all food animal production processes require identification of risks and points of control for health factors to guarantee quality. For the dairy industry, the determination of so-called Critical Control Points begins on the farm, with e.g. cow health and dairy hygiene. This, as the authors believe, is an area where a well-developed existing process has the potential to serve animal welfare.

The authors want this concept to deal with *all* factors contributing to animal welfare – so the need for a consistent definition of the term ‘welfare’ and its attributing factors as well as a scientifically designed basis for an animal health and welfare HACCP becomes clear again. The fact that since the possible adaptation of the HACCP concept to the dairy cow industry was first mentioned in 1997 by NOORDHUIZEN et al. no scientist has managed to design a scientifically based, consistent and usable dairy cattle HACCP plan supports this study’s findings that data published so far on this subject cannot be used for a risk assessment necessary for a HACCP plan. As long as this is the status quo, every assessment of the risks for dairy

cow lameness and decreased welfare remains estimation based on nothing more than common sense. In order to gain data on certain lameness risk factors to be used in an exposure and risk assessment, consistent – or at least comparable – methods and approaches for studies on this subject are necessary. Terms used need to be defined consistently, too, and a clear distinction needs to be made whether the studies focus on lameness or lesions. A few steps towards a risk assessment of dairy cow lameness and welfare have been undertaken in this study (see chapter 7), and may serve as a basis for further research on this subject.

9.2. Recommendations for Practical Implementation and Urgent Action

Resulting recommendations for *behavioural alterations and lameness scoring*:

- Behavioural alterations (way of standing or walking, time spent lying etc.) should be taken into consideration in deciding if a cow is lame or is going to be lame.
- Each dairy herd should have a routine lameness scoring program that fits the needs of the herd (problems) concerned.
- Records of regular lameness scoring procedures should be taken in order to evaluate them concerning statistics and changes in the herd situation.
- A lameness scoring system should contain specific terms and detailed definitions of each of the scores to make scoring as objective as possible.
- Lameness scoring should be used for detecting lame animals, and, at its best, to detect animals showing changes in gait and/or behaviour, before they become clinically lame.
- Some methods used in examining lame horses could be adapted to the examination methods usually applied on cows, like the Obel-grades.
- Some kind of quality management program should be designed for each farm individually: the problem, the situation, the circumstances given, the goal to be achieved, and the measures that can possibly be taken should be defined and recorded carefully.
- Some automated methods to detect lameness are being studied already (load distribution, pedometers); they need to be refined in terms of reliability and practicability under on-farm conditions.

- It would be useful to develop a scoring system that takes single gait attributes into account; scores would thus become more detailed, and chances of detecting lame animals even at an early stage, would become greater.
- Negative effects of subclinical lameness on cow welfare should be investigated.
- Therefore, research should determine which gait attributes are necessarily needed in a composite scoring systems. For this purpose, individual effects of claw pathologies on gait need to be identified.
- Research should evaluate how subjective assessments work when compared with more objective methods of assessing gait in dairy cattle; this seems necessary as in an on-farm situation the more 'traditional' methods will still be mostly used as technical equipment (such as cameras or scale-platforms) will not be available.

Resulting recommendations for *housing*:

- Tie-stalls should not be used as they reduce free movement of the cows and increase the risk of lameness.
- Cubicles and free stalls are the housing systems of choice; they should be thoroughly designed and provide enough space.
- The number of cubicles in a cubicle housing should be the same as the number of cows stabled.
- Comfortable lying places for every cow should be provided and the cubicle size should be chosen according to a cow's need of space.
- The relationship between cow behaviour and lameness needs to be studied as to gain useful suggestions for how housing systems for dairy cows may be modified or newly designed in order to reduce the incidence of health problems and improve the welfare of dairy cows.
- Behavioural differences between housing and pasture should be minimized through cubicle and free stall design.
- Management solutions that reduce excessive standing and walking on uncomfortable floors must be encouraged.
- More research on a cow's standing behaviour should be done.

- Animals should be given some time to adjust to a different floor surface, especially when they are changed from soft to hard floors. Heifers should be allowed to adjust to reduced exercise and walking on a concrete surface prior to introducing them to the dry-cow unit.
- Soft bedding should be provided in each cubicle or stall; cubicles should be made as comfortable as a straw yard for a cow.
- Concrete should not be used as flooring; at least, it should be covered with soft bedding material.
- The applicability of soft surface areas in traditional concrete flooring systems should be investigated.
- Research on long-term benefits of rubber flooring should be done.
- In both loose housing and tie-stalls measures should be taken to reduce the wetness and the faecal contamination of the floor.
- Regular exercise is beneficial for cow health and claw health; whenever no access to pasture can be permitted, exercise in specially designed areas is recommended.
- It is important to make sure the surface of the exercise area is dry and smooth in order to prevent it from causing hoof problems and in order to improve hoof health.

Resulting recommendations for *nutrition*:

- Thorough design of dairy cattle diets is needed to avoid metabolic disorders.
- Diets must meet the individual demands of the cow for fibre and energy, according to her stage of lactation, for example.
- An appropriate diet for the cow containing enough fibre out of forage needs to be designed to ensure rumen health.
- Energy density must meet the cows' needs.
- Food should be of good quality.
- Rations should be designed in order to prevent ruminal acidosis and laminitis.
- Changes in ration composition should be performed slowly to allow the rumen to adapt to the new composition.

- Particle size in ration should be thoroughly determined and should be high enough.
- A total mixed ration should be designed that meets the cows' nutritional needs; it may be necessary to produce different total mixed rations on one farm for different groups of cows.
- Accurate physiological diagnostic tests should be developed that will help detect subclinical acidosis and laminitis in a herd at an early stage.

Resulting recommendations for *management and stockmanship*:

- Herd size should be kept at a manageable level for the stockpersons.
- Herd size should be chosen according to the stall space available, or enough stalls should be provided, i.e. one for each cow to ensure that cows can lie down.
- Stockpersons should handle cows in a consistent, responsible and sensible way.
- Stockpersons should not make cows hurry along their track or treat them mean.
- Stockpersons should be trained at identifying lame cows at an early stage.
- Stockpersons should improve their knowledge about lameness, handling facilities and methods to treat a lame cow correctly.
- Stockpersons should record the lameness status of each cow regularly.
- A list of risks that can occur on a farm should be designed in order to categorise farms according to their risk intensity to animal health and welfare.

Resulting recommendations for *the role of the veterinarian and for claw trimming*:

- A cow's environment can be an important factor influencing lameness, so a veterinarian should observe and judge it critically.
- By conducting a herd health service, the veterinarian should provide up-to-date information as well as detect long-term developments, and he should give reasonable recommendations to the farmer.
- Lameness detection and prevention by means of a herd health program should be performed as it influences fertility and productivity in the herd and leads to better economic results for the farmer.

- By giving instructions and information to the farmer, the veterinarian should contribute to the farmer's economic success and cattle welfare.
- A thorough examination of a lame cow is necessary to find the reason causing the lameness.
- A veterinarian should bear in mind that a lame cow is suffering from some degree of pain, and should act accordingly.
- Posture scores and daily activity levels should be used by the farmer or veterinarian to assess pain in a cow.
- Pain in a cow can lead to a state called hyperalgesia, this should be considered in examining a cow, as the animal is more sensitive to further pain and even mere touching.
- Veterinarians should treat a lame animal by using pain-reducing drugs, so that the animal's well-being is not disturbed by prolonged pain.
- Regular claw trimming should be performed twice or three times a year.
- Thorough education is necessary for correct claw trimming, and modern facilities and tools should be used as this makes trimming easier for both the cow and the trimmer.
- Correct claw trimming should equalize the weight distribution between the claws and thus prevent claw lesions and lameness.

Resulting recommendations for *the genetic background of lameness*:

- Breeding programs for healthy feet should be encouraged.
- Animals with correct claw and leg angles should be selected for breeding.
- Bulls should be considered in terms of giving their genes to their progeny; cows are important, too, especially with modern techniques like embryo transfer on the rise.
- Claw and leg traits for breeding objectives should be carefully defined.
- The traits chosen should be tested for their usefulness in practical breeding work and according to the environment the animals are exposed to.
- Possible side effects on the musculoskeletal or other system should be avoided.

- Traits to be used in breeding work should consequently be related to susceptibility for claw and leg diseases on the one hand, and to management requirements such as low need for claw care and to functional aspects of locomotion on the other hand.
- As the most common cause of lameness is located in the claw, more selection pressure should be put on claw traits.

Summary

Beusker, Nicole: Welfare of Dairy Cows: Lameness in Cattle – A Literature Review.

Globally, livestock production is growing rapidly as a result of increasing demand for animal products. This holds also true for the dairy industry, the centre of which are dairy cows. Their health and welfare are important for efficient production and economic success. Lameness is seen as one of the most serious welfare problems for the dairy cow, and yet it is one of the least well-managed health problems of dairy cattle. This is due to the complex nature of lameness aetiology. A lot of isolated information on dairy cow lameness factors is available in the literature, but a concept is lacking with which to assess the cow's risk of developing lameness and suffering from pain.

By reviewing the literature on the subject of dairy cow lameness, the factors influencing lameness are analysed. These can be found in the type of housing, the kind of flooring, the amount of hygiene and daily exercise, nutritional concepts, management and stockmanship, veterinary care and pain control, claw trimming, and genetics. By causing lameness, they lead to economic losses for the farmer and to decreased welfare for the cows. Due to a shortage of a generally accepted definition of welfare, and due to inconsistent approaches to the determination of lameness influencing factors, no objective and consistent scientific assessment of dairy cow lameness and welfare has been developed so far.

This study tried a practical approach to develop a scheme for a possible risk assessment on this issue, and weak points in the existing concepts and proposals, which need to be dealt with by future research, were worked out. Taking the food industry HACCP concept as a basis, proper definitions as well as hazard identification and hazard characterisation of factors influencing dairy cow lameness and welfare are established. Although a complete scientific risk assessment of dairy cow lameness and welfare cannot be carried out in this study due to a shortage of consistent and scientifically based data, a practical approach to a risk assessment is carried out judging hazard characterisation and exposure assessment as gained by the literature review. This can be used as a basis for the development of future risk assessment and control programs aimed at increasing dairy cow welfare.

Zusammenfassung

Beusker, Nicole: Zum Wohlbefinden von Milchkühen: Lahmheit bei Rindern – eine Literaturkritik.

Weltweit wächst die Produktion tierischer Lebensmittel stetig an, so auch im Milchkuhsektor. Im Zentrum dieses Produktionssystems steht das Lebewesen Kuh, deren Gesundheit und Wohlbefinden entscheidend sind für eine erfolgreiche Produktion und finanziellen Erfolg der Rinderhalter. Lahmheit ist eines der größten und zugleich eines der am mangelhaftesten kontrollierten Tierschutzprobleme in der Milchkuhhaltung, das zu wirtschaftlichen Verlusten für den Landwirt und zu einem eingeschränkten Wohlbefinden der Kühe führt. Die komplexe Natur der Ätiologie von Lahmheit spielt hier eine Rolle. In der Literatur finden sich Studien, die einzelne Einflussfaktoren isoliert betrachten, aber es existiert kein Konzept, mit dem das Risiko einer Kuh, lahm zu werden und unter Schmerzen zu leiden, bewertet werden kann.

Indem eine Rezension der Literatur zum Thema ‚Lahmheit bei Milchkühen‘ vorgenommen wird, stellt diese Arbeit die Wichtigkeit der Thematik für die Forschungsgemeinde und die Öffentlichkeit dar. Mit Hilfe einer Literaturübersicht werden die Faktoren, die Lahmheit bei Milchkühen beeinflussen (können), dargestellt und charakterisiert. Lahmheit bei Milchkühen wird von einer Vielzahl an Faktoren beeinflusst, die sich in den Bereichen Stallkonzeption, Stallboden, Hygiene, Bewegungsfreiheit und Menge an Bewegung, Fütterung, Management durch den Landwirt, tierärztliche Versorgung und schmerzlindernde Behandlung sowie Klauenpflege und genetische Parameter finden. Diese Faktoren lassen sich für die Milchkuhhaltung nicht getrennt voneinander betrachten, sondern treten in der Regel in unterschiedlichen Kombinationen (je nach Stallgegebenheiten) auf und beeinflussen sich gegenseitig.

Die Herausarbeitung der Lahmheit beeinflussenden Faktoren aus der Forschungsliteratur dient als Basis für den Versuch der Erstellung einer Risikobewertung dieser Faktoren im Hinblick auf ihre Gefährlichkeit, Lahmheit bei Milchkühen auszulösen und so das Wohlbefinden der Tiere einzuschränken. Als Grundlage für eine Risikobewertung wird das in der Lebensmittelindustrie etablierte HACCP-Konzept (Hazard Analysis and Critical Control Point) gewählt. Die zentralen Begriffe des Konzepts sowie die vier Stufen der Risikobewertung (Gefahrenidentifizierung, Gefahrenbeschreibung, Expositionsabschätzung und Risikobeschreibung) werden für den Gebrauch im Milchkuhbereich modifiziert und angepasst. Die Gefahrenidentifizierung und -beschreibung werden mit Hilfe der aus der Literaturübersicht gewon-

nenen Einflussfaktoren vorgenommen, und eine Liste von Faktoren, die Lahmheit beeinflussen, wird so erstellt. Eine Expositionsabschätzung und Risikobeschreibung sind aufgrund der uneinheitlichen und in wissenschaftlicher Hinsicht nicht vergleichbaren Daten nicht möglich, so dass eine wissenschaftliche Risikobewertung misslingt, und dafür eine praktisch orientierte Risikobewertung der Einflussfaktoren auf Lahmheit vorgenommen wird. Dabei tritt der Landwirt als der entscheidende Risikofaktor in den Vordergrund, da er der einzige der Faktoren ist, der selbst Entscheidungen treffen kann und der über die Ausprägung der anderen Faktoren aktiv bestimmen kann.

Obwohl eine wissenschaftliche Risikobewertung im Sinne des HACCP-Konzeptes nicht in all ihren Schritten vorgenommen werden konnte, dienen die adaptierten Definitionen und die durchgeführte Gefahrenidentifizierung und -beschreibung als Ausgangspunkte für zukünftige Forschungen auf dem Gebiet der Verfahrenskontrolle und Risikobewertung in der Milchkühhaltung. Es bleibt weiteren Forschungen überlassen, einheitliche Definitionen für Begriffe wie ‚welfare‘ und ‚cow comfort‘ zu finden, die bisher noch nicht etabliert wurden, und es bleibt ebenso Sache weiterer Forschung, einheitliche Methoden und Ansätze von Studien zum Thema ‚Lahmheit bei Milchkühen‘ zu generieren, um vergleichbare und für eine Risikobewertung brauchbare Daten zu erhalten. Diese definatorischen Schwachstellen der Thematik, die einhergehen mit einem freiwilligen Erkenntnisverzicht der Forschungsgemeinde, gilt es zu beseitigen, um ein einheitliches und wissenschaftlich fundiertes Risikobewertungskonzept zum Thema Lahmheit bei Milchkühen erarbeiten zu können.

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