Foot disorders in dairy cattle

A socio-economic approach to improve dairy cow welfare

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Abstract

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Foot disorders and the resulting lameness are the most important welfare problem in modern dairy farming. Despite much knowledge about foot disorders and their risk factors, a reduction in the prevalence of foot disorders and lameness has not been achieved. To improve dairy cattle welfare, it is important to increase the awareness of stakeholders. Therefore, the aim of this thesis is to increase the awareness about the problem of foot disorders in dairy farming. A socio-economic approach is used to gain insight into this welfare problem and find strategies to improve dairy cow foot health.

The first part of the thesis, based on modeling, aims to gain more insight into the consequences of different foot disorders, clinical and subclinical, and the intervention measures to improve dairy cow foot health. The model studies, using a dynamic stochastic simulation model, aimed at both the economic losses and consequences for dairy cow welfare. The economic consequences included costs due to milk production losses, premature culling, prolonged calving interval, labor of the dairy farmer, costs for the foot trimmer, visits of a veterinarian, treatment costs, and discarded milk. For a default farm the costs averaged €3,474 per year; an annual loss of €53 per average cow in the herd. The costs of subclinical foot disorders make up 32% of all costs due to foot disorders. To calculate the welfare impact, the pain scores for each foot disorder in clinical and subclinical stage were estimated and used in the simulation model. The pain was used as an indicator as it was assumed to reflect the impact on all three aspects of animal welfare (health and functioning, feeling, natural living). On average each cow in the herd obtains a negative welfare impact score of 12, which is 20% of the maximum welfare impact score. Clinical foot disorders caused 46% of the welfare impact due to foot disorders. The considerable impact of subclinical foot disorders implies that the problem is likely to have more impact than stakeholders are aware of. Intervention measures were modeled when they were applicable on a dairy farm with cubicle housing. The model outcomes indicated that improving lying surface and performing additional foot trimming were cost-effective measures. Reducing stocking density was assessed to be break even. The improved lying surface and reduced stocking density also have a relative high welfare benefit. The model studies revealed gaps in knowledge about the problem of foot disorders and directions for new studies have been indicated.

The second part deals with moral and social aspects. It was explored whether longevity is both a morally relevant aspect in the discussion on killing animals and a constitutive element of animal welfare, rather than as a mere indicator of animal welfare. This exploration included two steps. A first step entails a shift from welfare as a concept based mainly on biological knowledge to the notion that animal welfare is based on and informed by biological knowledge but is equally driven by moral norms. The second step entails a

shift from views on animal welfare in terms of functioning or feeling well to a view on animal welfare that includes the aspect of natural living in which species-specific preferences and species-specific development are important. In the practice of dairy farming the inclusion of longevity in welfare assessment implies that premature culling is not a neutral act, but one that can affect animal welfare because of its implications for the longevity of a cow. Furthermore, insight was gained into the attitude of dairy farmers regarding dairy cow foot health and their intention to take action to improve dairy cow foot health. The Theory of Planned Behavior (TPB) was used to determine drivers and barriers to take action. Most farmers intended to improve dairy cow foot health, however, the intention was moderate. Most important driver seemed to be the achievement of better foot health with cost-effective measures. Possible barriers to taking action were labor efficiency and the effect of achieving an improved dairy cow foot health only a long time after taking action. It seemed that measures other than the routinely and already familiar ones were not an option for most farmers. The feed advisor and foot trimmer seemed to have most influence on intentions to take action to improve dairy cow foot health. Subclinical foot disorders were not valued as important with respect to animal welfare. Moreover, 25% of the respondents did not believe cows could suffer pain. Most farmers did indicate that good care for the cows is important, but that was not associated with the intention to improve dairy cow foot health.

In this thesis it is concluded that, based on developments in our valuing of and dealing with animals, the current situation with regard to dairy cow foot health is not acceptable. The farmer is the one responsible to provide for good health and welfare of the cows. However, the interpretation of animal welfare by most farmers, a restricted view on function and health, is different from the broader concept of animal welfare as proposed in this thesis and also differs from the concept people hold in society. Furthermore, a farmer needs to weigh the importance of improving foot health, and animal welfare, against other issues at the farm. In order to achieve improvements in dairy farming, the whole sector needs to acknowledge animal welfare as a concept that entails more than health and functioning. This will lead to an increased importance of improving dairy cow foot health, making it more a priority to take concerted action.

Voorwoord

Mijn proefschrift is klaar! Na ruim 4 jaar onderzoek naar socio-economische aspecten van klauwaandoeningen bij melkvee is het proefschrift klaar. De klauwproblematiek is nog niet opgelost, maar ik hoop met dit proefschrift belangrijke steentjes te hebben aangedragen om het welzijn van melkvee te verbeteren. Hopelijk zijn er genoeg steentjes om tot *goed lopende* oplossingsstrategieën te komen. Dit promotietraject was voor mij een interessante en leerzame periode. Zeker ook uitdagend; inhoudelijk om de verschillende disciplines goed te leren kennen, toe te passen en bij elkaar te brengen. Maar ook persoonlijk, omdat het soms voelde alsof ik met de klauwproblemen op een eiland zat. Toch zat ik natuurlijk niet echt op een eiland en zijn er verschillende mensen belangrijk geweest voor mijn onderzoek. Iedereen die een bijdrage heeft geleverd om dit project te kunnen voltooien, wil ik via deze weg heel hartelijk bedanken!

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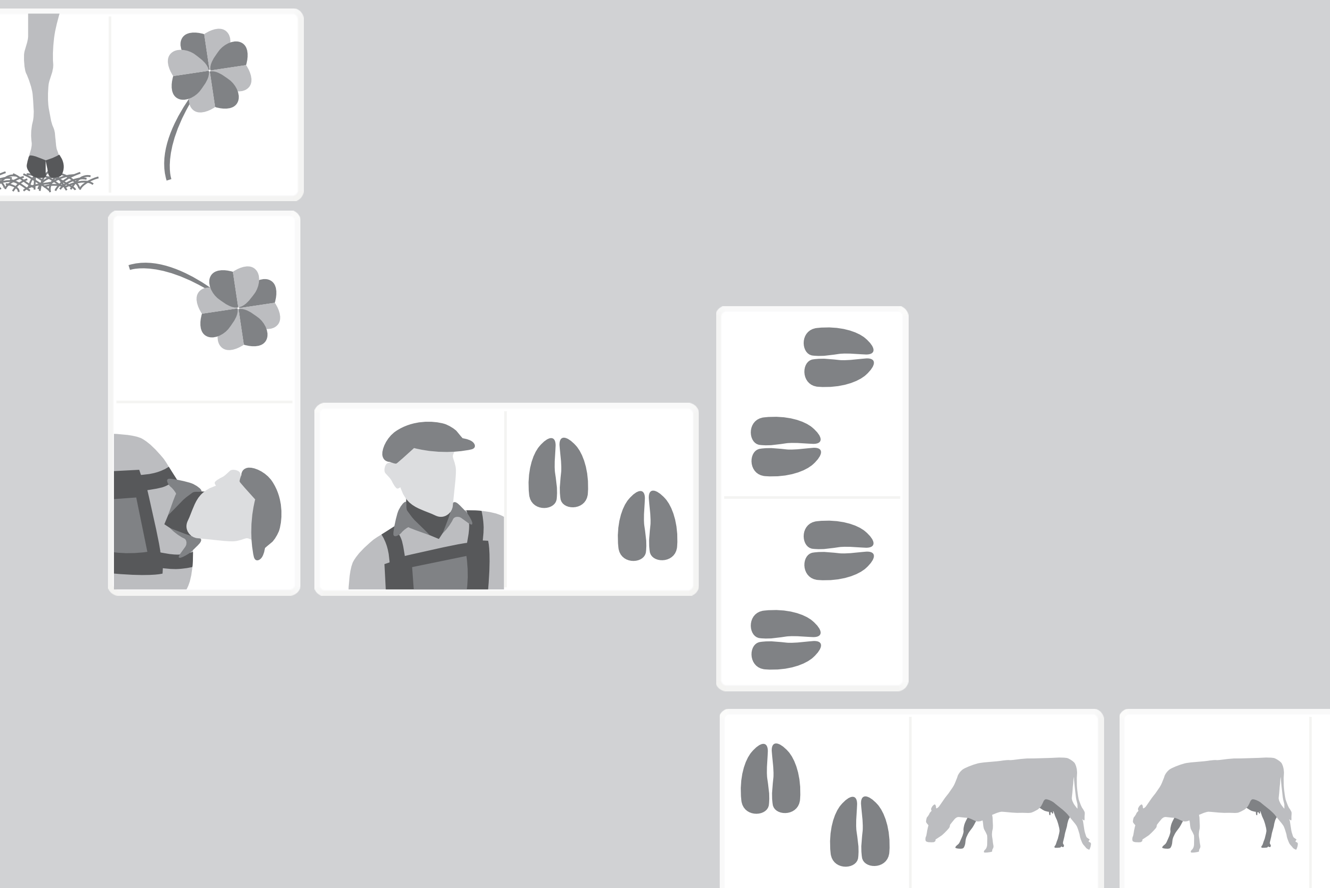
Chapter 1

Introduction



Introduction

Healthy feet are very important for the welfare of dairy cattle. Foot disorders and the resulting lameness are considered to be the most important welfare problem in dairy farming according to the parameters incidence, severity and duration (Anonymous, 2001; Rushen, 2001; Whay et al., 2003a; Algers et al., 2009). Besides, together with mastitis and reproductive problems, lameness has appeared to be an important cause of financial losses (Enting et al., 1997; Kossaibati and Esslemont, 1997).

Nowadays more than 90% of the dairy cows in The Netherlands are housed in cubicle housing systems, with mainly concrete flooring (CBS, 2009). This system was introduced in the 1970's and 1980's. Previously, the main housing type in The Netherlands was tie stall housing. During winter the cows in a tie stall were tied, stood side by side and were fed and milked on the same place, while during summer the cows were pastured 24 hours per day and were milked in the pasture. The introduction of the cubicle housing system meant a major change for dairy cow and farmer. In cubicle housing, cows can walk around in the alleys, go to the feeding fence and drinking trough, and lay down in the cubicles. The cows are milked in the milking parlor, or by an automatic milking system. During summer the cows are mainly pastured only during day time. The number of farms which applies pasturing is decreasing (80% in 2007 to 74% in 2010; CBS StatLine). Keeping cows in cubicle housing is an efficient way of dairy farming, with the labor efficiency as an important effect for the farmer. The increased labor efficiency enabled farmers to keep more cows without the need to hire more labor input. A disadvantage of managing more cows per person is that the individual attention for the cows is likely to reduce. Furthermore, the management and certain aspects of modern housing are accompanied by presence of production diseases like mastitis, fertility problems and foot disorders (Fourichon et al., 2000; Somers et al., 2003; Jansen et al., 2009).

It is expected that worldwide the demand for milk will gradually increase (IDF, 2011). Furthermore, at this moment, dairy farming is on the verge of major changes because the milk quota regulation in the EU will end in March 2015. Liberal market principles will influence the dairy sector which will result in a more volatile milk price (LEI, 2008). The costs of milk production will therefore become more important. As a consequence, it is generally expected that the number of dairy farms will reduce substantially and that the coming ten years in The Netherlands the number of dairy cows per farm will further increase to 150 cows per farm (Galama and Rienks, 2010). Consequently, the quality of housing and management on a limited number of farms has a major impact on a number of animals. Attention for the most important health problem with respect to welfare is then even more important.

Foot disorders and lameness

Foot disorders are multi-factorial by nature and are caused by various risk factors. The causes for lameness and foot disorders are related to housing conditions, cow characteristics, like breed and parity, and the management on the farm (e.g., Alban, 1995; Vaarst et al., 1998; Somers et al., 2005; Holzhauer et al., 2008). This thesis includes both the foot disorders in clinical stage (cows being visibly lame) and foot disorders in subclinical stage (cows not being clearly visibly lame, but visible during inspection of the feet). As stated by Somers (2004) "not visually lame does not imply that an animal is not suffering". The prevalence of foot disorders, both clinical and subclinical, in dairy cows in The Netherlands is more than 80% when the cows are kept in cubicle housing with concrete flooring (Somers et al., 2003). According to Enting et al. (1997) the incidence of lame cows was 25% in The Netherlands. When cows are kept in straw yards the prevalence is less than 60% and the foot disorders are less severe. Besides, research also revealed that 5% of the cows kept on concrete floors were lame during the whole year (Somers, 2004). Foot disorders account for 90% of the cases of lameness in dairy cattle (Murray et al., 1996). The incidence and prevalence of foot disorders and lameness vary considerably between farms (e.g., Clarkson et al., 1996; Whitaker et al., 2004). And, for example, digital dermatitis (DD) and interdigital dermatitis and heel horn erosion (IDHE), two highly prevalent foot disorders, showed variation between herds of 1 – 65% for DD and 2 – 93% for IDHE in cubicle housing systems (Somers et al., 2003).

Each type of foot disorder has its own pathology and with that specific risk factors. The seven most important foot disorders are: interdigital phlegmon (IP), interdigital dermatitis and heel horn erosion (IDHE), digital dermatitis (DD), sole hemorrhage (SoH), white line disease (WLD), sole ulcer (SUL), and interdigital hyperplasia (HYP). IP, IDHE and DD belong to the group of infectious foot disorders. SoH, WLD, SUL and HYP are caused by physical or metabolic disturbances or are secondary by nature (i.e. they follow after another lesion). IP, being described in different terms like interdigital necrobacillosis and foul in the foot, is an acute inflammation of the subcutaneous tissues of the interdigital space and adjacent coronary band associated with *Fusobacterium necrophorum* and causes a sudden severe lameness (Alban et al., 1995; Blowey and Weaver, 2003). Interdigital dermatitis and heel horn erosion (IDHE) were taken together as in other studies (Peterse, 1980; Somers et al., 2003). IDHE is an epidermitis of the interdigital skin extending to the dermis: in many cases the infection extends to the heel horn. IDHE is an infectious disease caused by different organisms (*Fusobacterium necroforum, Dichelobacter nodosus, Treponeme spirochete*)(Van Amstel and Shearer, 2006b). DD is an infection of the epidermis of the hoof skin (Blowey and Weaver, 2003) caused by spirochetes called Treponems (Watson, 2007). SoH is the result of metabolic disturbances and physical damage due to overloading and pressure on the claw, especially with concrete flooring (Van der Tol et al., 2003). In the literature, the terms 'laminitis' and 'sole hemorrhage' are used interchangeably. In this research the terms sole hemorrhage, subclinical laminitis, laminitis or chronic laminitis are referred to as SoH. Hemorrhages and lesions in the white line are categorized as WLD. WLD is mainly caused by physical damage, like separation of the white line due to sharp turning on concrete or penetration of stones. SUL, also described as pododermatitis circumscripta, is a secondary foot disorder and occurs after foot disorders like SoH and IDHE or after trauma (Van Amstel and Shearer, 2006a). As in the study by Somers et al. (2003) SUL applies to all ulcers in the sole, toe and heel. HYP, also referred to as tyloma or fibroma, originates as a reaction to long lasting inflammation of the interdigital cleft by DD or IDHE (Blowey and Weaver, 2003; Van Amstel and Shearer, 2006b; Watson, 2007). The disorder is recognizable by proliferation of the interdigital skin. For the infectious foot disorders examples of risk factors are prolonged standing in slurry, high infection pressure, introduction of cows into the milking herd and lesions making it easier for bacteria to penetrate (e.g., Somers et al., 2005; Holzhauer et al., 2006b). For the foot disorders relating to lesions of the claw, important risk factors are prolonged standing on concrete, lack of space in the alleys, inadequate bedding in cubicles and cubicle-size, slippery alleys and stones or foreign bodies, inaccurate feeding and claw shape (Van der Tol et al., 2003; Bell, 2005; Cook and Nordlund, 2009; Cramer et al., 2009).

Animal welfare

Concern about the problem of foot disorders with respect to animal welfare is expressed by different organizations, like EFSA (Algers et al., 2009) and the Farm Animal Welfare Council (FAWC, 2009). Animal welfare is an important issue for all stakeholders in Western Society, from producer to retailer to consumer (Bracke et al., 2005). The societal concern about farm animal welfare makes it even more important to reduce the problem of foot disorders in dairy farming. Animal welfare is a concept which is interpreted in various ways. Citizens, people in society, give much value to naturalness, which means being able to move freely and having access to pasture (Te Velde et al., 2002; Boogaard et al., 2008). Farmers focus on other aspects of animal welfare. They focus more on good physical health and production levels by providing care, which means protection and providing feed and water (Te Velde et al., 2002; De Lauwere and De Rooij, 2010). Animal scientists have yet another focus which is on the feeling of the animals and ability to cope with the environment (e.g., Broom, 1986; Bracke and Hopster, 2006; Broom, 2007). This shows there is a large difference in the interpretations of animal welfare between different groups of people, but also within these groups difference in values and focus points exist (De Greef et al., 2006; De Lauwere and De Rooij, 2010).

In this thesis, Fraser's view on animal welfare (Fraser et al., 1997) has been used as starting point. This means that all three aspects, namely a) health and functioning, b) feeling and c) natural living are important for animal welfare. Furthermore, these aspects do relate and overlap, as also illustrated by Von Keyserlingk et al. (2009), and include the five freedoms (FAWC). This means that animals should be provided with good feed and water, should be free from diseases and should function well. In case of dairy cattle this means for example a good level of milk production achieved by good feeding, having few problems with fertility or udder health problems, skin lesions or foot disorders by providing protection and care for the animals. Furthermore, it means that animals are free from pain or discomfort and free from long term stress, which will be achieved by preventing diseases to achieve a good health, accurate treatment and pain relief when there are health issues and providing a comfortable environment so animals are able to cope with stressors. The animal should also be able to perform species-specific behaviors, needed to cope with the environment and fulfill species-specific needs. For a dairy cow, a ruminant, this implies for example, the need to walk and move freely to explore, and to lie down comfortably to ruminate and rest. Foot disorders, and the resulting lameness, have a great impact on all these aspects of animal welfare. It increases the risk of other health problems, causes much pain, and with that foot disorders impair the ability to walk and move freely, perform normal cow behavior and fulfill cow specific needs without pain.

A socio-economic approach to improve dairy cow foot health

Despite a considerable knowledge about foot disorders and their risk factors, no reduction in the prevalence of foot disorders and lameness has occurred (Somers et al., 2003; Whay et al., 2003b). Besides, dairy farmers underestimate the problem of foot disorders as well as the relation with lameness (Mill and Ward, 1994; Whay et al., 2002). Various reasons can explain the underestimation of this problem, for example, it could be that farmers are used to the problem and consider foot disorders as part of their system. Moreover, it should be considered that cows are prey animals that may show little behavioral response to a significant degree of pain (O' Callaghan et al., 2003).

A noteworthy aspect with respect to foot disorders is that a considerable difference in diagnosis exists between observers (Holzhauer et al., 2006a) and between farmer and researcher (Whay et al., 2003b). This is an issue to consider when advising application of treatment, adjustment of farming practices or housing facilities. Whitaker et al. (2004) state that there is much useful knowledge, but that it is hard to convince farmers that financial benefits can be achieved. Bell et al. (2009) showed that a lameness control program was ineffective, mainly caused by a lack of compliance of the dairy farmers. Furthermore, despite the knowledge about foot disorders and their risk factors, up-to-date and specific information on the economic consequences and welfare impact of foot disorders and possible intervention measures is lacking. The abovementioned implies that approaches to improve dairy cow foot health lie more in socio-economics, than in more research in pathology and risk factors of the various foot disorders (Algers et al., 2009). The farmer is the one making the decisions about management and housing of the dairy cows. The farmer, being the animal keeper, is responsible for the health and welfare of the cows and, therefore, is the one who has to establish the improvement. By presence of health problems, the farmer is the one deciding to treat or cull a cow.

This role of the farmer indicates the importance to make farmers more aware of the problem, because being unaware of the economic and welfare consequences of foot disorders leads to underestimation of the problem and with that a lacking commitment to take action for improvement of dairy cow foot health. In order to increase awareness, it is important to gain insight into the impact of foot disorders on animal welfare and economics and the effects of taking intervention measures. Furthermore it is important to gain insight into the attitude of dairy farmers towards the effects of foot disorders on economics and animal welfare and into their attitude and intention to take action to improve dairy cow foot health. Knowledge about factors explaining attitude towards the importance of this welfare issue and actions to improve the situation will lead to more effective approaches to improve the situation.

Aim of the thesis

The aim of this thesis is to increase the awareness about the problem of foot disorders in dairy farming. A socio-economic approach will be used to gain insight into this welfare problem and to find strategies to improve dairy cow foot health. The research in this thesis consists of two parts. One part, based on modeling, aims to gain more insight into the consequences of foot disorders and the intervention measures to improve dairy cow foot health. Aiming at both consequences for the farmer, in terms of economic losses, and consequences for the dairy cow, in terms of animal welfare. The other part deals with the social and moral aspects. This part includes a discussion about the concept of animal welfare. The question whether longevity is an issue of animal welfare is considered. Followed by a study into the attitude of dairy farmers with respect to dairy cow foot health and the intention to take action for its improvement. The thesis will finish with an analysis of the role of the dairy farmer with respect to this health problem. The following research objectives have been formulated:

- Assessment of the economic consequences of different foot disorders (impact on dairy farmer) (chapter 2);
- Assessment of the welfare impact of different foot disorders (impact on dairy cow) (chapter 3);
- Assessment of the effect of intervention measures to improve dairy cow foot health, regarding economic consequences and welfare impact (chapter 4);

- Explore whether longevity should be considered as an animal welfare issue (chapter 5);
- Gain insight into the attitude of dairy farmers concerning dairy cow foot health and intention to take action for its improvement (chapter 6);
- Analyze the role of the dairy farmer with respect to improvement of dairy cow foot health (chapter 7).

The ultimate aim of this thesis is to contribute to the improvement of dairy cattle welfare by finding new strategies to improve dairy cow foot health. The research is multidisciplinary, using different research fields in animal science (animal welfare, animal health (focus on foot health), epidemiology) and social sciences (economics, modeling, social psychology/behavioral science, animal ethics). The outcomes will be shared with various stakeholders in the dairy industry, such as dairy farmers, (council) organizations and policy makers. The outcomes will give farmers and policy makers insight in priorities to be set in the approach to improve dairy cow foot health, based on respect for the farmer and the animal and with societal support.

Outline of the thesis

The first part in this thesis aims at gaining insight into the economic and welfare consequences of foot disorders in dairy cattle and of the measures for improvement thereof. Model studies have been executed by using the existing knowledge. The scientific literature available and expertise from experts in the field of dairy farming and dairy cow foot health have been used for the input needed to build the models. C*hapter 2* describes a dynamic stochastic Monte Carlo simulation model that has been built to estimate the economic losses for the farmer. Epidemiological data about foot disorders are used to simulate the occurrence of the subclinical and clinical stages of foot disorders (incidence and duration) on a common Dutch farm with cubicle housing and pasturing during summer. In order to assess the economic consequences due to foot disorders, data on the different cost factors (such as milk production losses, labor costs) are related to the presence of the different foot disorders. In *chapter 3*, the same model has been used to assess the impact on dairy cow welfare. The estimated pain impact of each foot disorder is used to calculate the welfare impact, taking into account the incidence, severity and duration. The pain due to foot disorders, expressed in affected locomotion, is used as an indicator to represent all elements of animal welfare which are divided over the three main aspects of ‘functioning and health’, ‘feeling’ and ‘natural living’. In *chapter 4* the model is used to simulate the effect of different intervention measures on the economic and welfare impact of the different foot disorders. The intervention measures applied to measures applicable on a common dairy farm with cubicle housing.

The second part deals with moral and social aspects of the problem of foot disorders. In *chapter 5* the moral relevance of the problem of foot disorders has been emphasized by exploring the question whether longevity should be considered as an animal welfare issue. The modeling process to assess the impact of foot disorders on dairy cow welfare gave rise to this question. One of the weighing choices in the welfare assessment was the question whether and how the premature culling of dairy cows due to foot disorders should be weighed. In *chapter 6* the attitude of the dairy farmer about the importance of dairy cow foot health and the intention of dairy farmers to improve dairy cow foot health is described. A questionnaire among Dutch dairy farmers has been held, using the Theory of Planned Behavior, followed by some in-depth interviews to provide a better understanding of the results from the questionnaire. Chapters 2 through 6 give input to integrate and discuss the findings of the research in *chapter 7*. Moreover, in this final chapter, the role of dairy farmers with respect to the improvement of dairy cow foot health will be discussed and finally the conclusions and recommendations will be given.

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Chapter 2

Assessing economic consequences of foot disorders in dairy cattle using a dynamic stochastic simulation model

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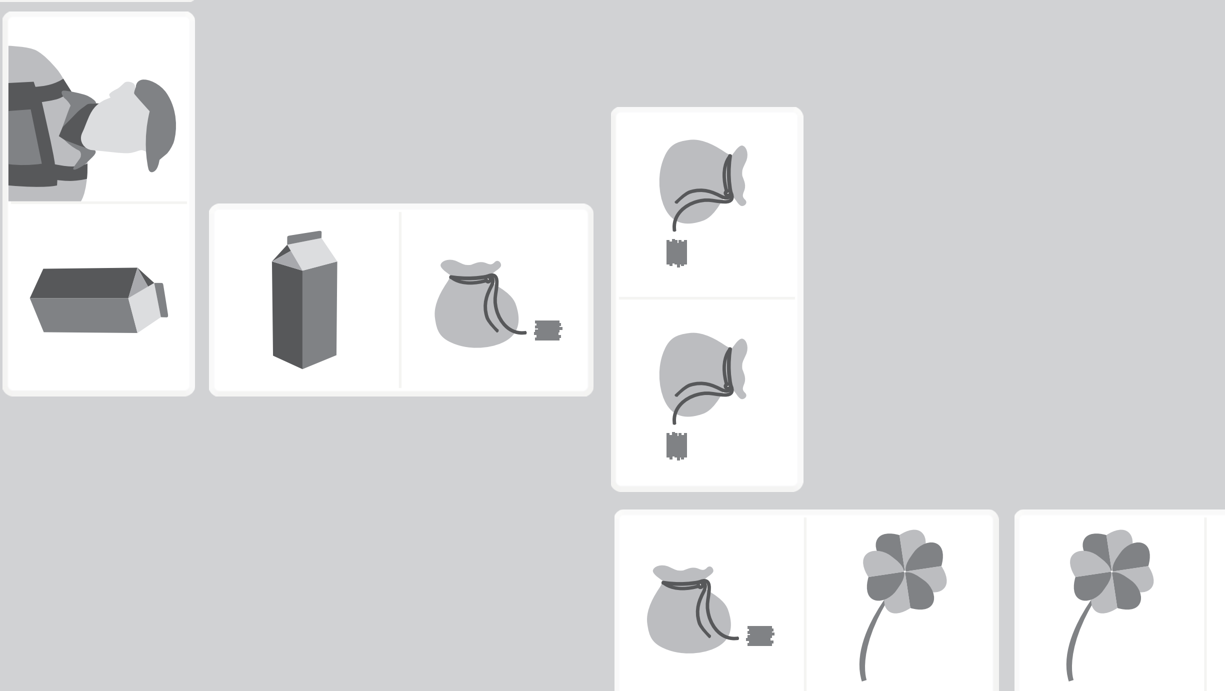

Abstract

Foot disorders are an important health problem in dairy cattle, in terms of economics and animal welfare. The incidence, severity, and duration of foot disorders account for their importance. Prevalence of both subclinical and clinical foot disorders is high. More insight into the economic consequences could increase awareness among dairy farmers and could be an incentive for them to take action on this problem of animal welfare. The objective of this research was to estimate the economic consequences of different types of foot disorders, both clinical and subclinical. A dynamic stochastic Monte Carlo simulation model was used, taking into account the different types of foot disorders. The economic consequences of foot disorders modeled were costs due to milk production losses, culling, prolonged calving interval, labor of the dairy farmer and the foot trimmer, visits of a veterinarian, treatment, and discarded milk. Under the milk quota system in The Netherlands, costs due to foot disorders for a default farm with 65 cows averaged €3,474 per year (ranging from €2,282 to €4,965), an annual loss of €53 per cow. This calculation implies that the costs due to foot disorders are more substantial than farmers might think. The costs of subclinical foot disorders account for 32% of all costs due to foot disorders. The costs due to foot disorders that are present without treatment or detection by the farmer are considerable. This finding implies that farmers might underestimate the benefits of taking action earlier and more thoroughly. A clinical foot disorder costs, on average, €67, and a subclinical foot disorder €13. The highest costs classified by foot disorder were those due to digital dermatitis, which has a high incidence and relatively high clinical prevalence. The highest costs classified by cost factor were those due to milk production losses and culling. Sensitivity analysis showed that variables regarding milk production were important for economic costs due to foot disorders. Furthermore, the probability of getting a foot disorder and probability of cure were important for estimating the costs due to foot disorders. Farmer awareness concerning dairy cow foot health and taking action more thoroughly, therefore, could reduce the economic consequences and improve welfare simultaneously.

Key words: dairy cow, foot disorder, economic modeling, Monte Carlo simulation

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Introduction

From both an economic and an animal welfare point of view, foot disorders are an important health problem in dairy cattle. The high incidence, severity and duration of foot disorders account for their importance (Clarkson et al., 1996; Dyer et al., 2007; Frankena et al., 2009). Foot disorders and the resulting lameness cause serious economic losses for the farmer. Together with mastitis and reproductive problems, foot disorders are regarded as the most important health problem causing economic losses (Enting et al., 1997; Kossaibati and Esslemont, 1997).

Foot disorders are an important problem for dairy cows kept in cubicle housing systems (Clarkson et al., 1996; Somers et al., 2003; Cramer et al., 2008). Most of these foot disorders are subclinical (i.e. do not cause lameness; Clarkson et al., 1996; Espejo et al., 2006; Dyer et al., 2007). Studies into risk factors and possible intervention strategies are numerous (Bergsten, 2003; Somers et al., 2005a,b). Despite this amount of knowledge in the field of foot health of dairy cattle, there is no reduction in prevalence and incidence of foot disorders (Somers et al., 2003; Whay et al., 2003). Lameness control programs have not yet been successful. This is mainly because of lack of compliance in the program by the farmer and veterinarian (Bell et al., 2009). This is critical because improvement in dairy cow foot health depends primarily on the dairy farmer. More insight into the economic consequences of foot disorders can make the farmer more aware of the problem. A few cost estimations have been published (Enting et al., 1997; Kossaibati and Esslemont, 1997). These estimations are older and limited in their scope as they only look at lameness (clinical foot disorders), do not differentiate between different foot disorders, and do not take into account their duration.

Different types of foot disorders can be distinguished. Some foot disorders, such as digital dermatitis and interdigital phlegmon, are infectious and mainly related to the skin. Other foot disorders (e.g., sole hemorrhages and white line diseases) are caused largely by physical or metabolic disturbances and occur in the sole of the claw or are secondary in nature (e.g., sole ulcer and interdigital hyperplasia). Each of the different foot disorders has a specific effect on the welfare of the dairy cow and on the economic consequences because they differ in incidence, severity and duration.

The development of a disease and its detection by dairy farmers vary among the different foot disorders: some are detected easily, whereas others are difficult to detect. For example, interdigital phlegmon is a very acute foot disorder, and practically all cases are detected easily and treated successfully. This foot disorder occurs mostly on one leg at a time and makes cows visibly lame. It causes intense discomfort for the cow for a brief period. On the other hand, interdigital dermatitis and heel erosion develop slowly and commonly occur on both hind hoofs. It causes increasing discomfort for the cow and milk production losses to the farmer for a longer period. The losses per day are relatively low but accumulate over a longer period. However, the detection of bilateral foot disorders is less probable. A cow with bilateral foot disorders walks tenderly rather than being obviously lame. This is part of the natural response of a cow, as a prey animal, to minimize the response to pain (O' Callaghan et al., 2003), and it adds to the underestimation of the problem of foot disorders, especially for bilateral foot disorders, because a cow then cannot relief one painful foot. The objective of this study was to estimate the economic consequences of foot disorders in dairy cattle, taking into account clinical and subclinical foot disorders and the dynamics of different types of foot disorders, using a dynamic stochastic Monte Carlo simulation model.

Materials and Methods

Model overview

A dynamic discrete event Monte Carlo simulation model was developed. Monte Carlo simulation is a computer simulation technique, in which a simulation model is run repeatedly. Specific values for the parameters in the model for each individual iteration are drawn from relevant distributions. The naturally occurring variation in a biological system can thus be encompassed. The dynamic stochastic model was developed in Excel (Microsoft Corp., Redmond, WA) using add-in software @Risk (Palisade Corporation, Ithaca, NY).

The basic stochastic process is carried out at the cow level. In the first step, the model simulated cow characteristics of a herd of 65 dairy cows. In the second step, the model simulated the dynamics of foot disorders per cow per month for 2 complete calendar years. In this way, a steady state situation was achieved at the beginning of year 2. In the third step, the results from year 2 were used for the calculation of the economic consequences of the simulated foot disorders. The fourth step involved the summation of results for the herd of 65 cows. To obtain a stable mean outcome and to determine the variation between the herds, 500 herds were simulated.

Information for input variables for this dynamic discrete event model was derived from scientific literature or, if no literature was available, based on the authors’ expertise. Literature was selected on relevancy and reliability, based on the number of herds and dairy cows in the study, the scoring methods used, and the breed of the cows and housing system. The model is described in more detail in the following paragraphs.

Foot disorders

In this study, foot disorders are classified as subclinical or clinical based on experimental assessments (Manson and Leaver, 1988; Bicalho et al., 2007a). Obviously lame cows and cows walking tenderly are considered as lame cases. The following foot disorders were modeled: interdigital phlegmon (IP), interdigital dermatitis and heel horn erosion (IDHE), digital dermatitis (DD), sole hemorrhage (SoH), white line disease (WLD), sole ulcer

(SUL), and interdigital hyperplasia (HYP). Interdigital phlegmon, IDHE and DD are infectious foot disorders; SoH, WLD, SUL and HYP are caused by physical or metabolic disturbances or are secondary by nature.

Interdigital phlegmon, also called interdigital necrobacillosis or foul in the foot, is an acute inflammation of the dermal layers of the interdigital space and adjacent coronary band associated with *Fusobacterium necrophorum* and causes a sudden, severe lameness (Blowey and Weaver, 2003). Interdigital dermatitis and heel horn erosion were taken together as in other studies (Somers et al., 2003). IDHE is an epidermitis of the interdigital skin extending to the dermis: in many cases the infection extends to the heel horn. IDHE is an infectious disease caused by different organisms. Digital dermatitis, often called Mortellaro's disease, is an infection of the epidermis of the hoof skin (Blowey and Weaver, 2003). Sole hemorrhage is the result of metabolic disturbances and physical damage due to overloading and pressure on the claw. In the literature, the terms 'laminitis' and 'sole hemorrhage' are used interchangeably. In this study, we classified sole hemorrhage, subclinical laminitis, laminitis or chronic laminitis as SoH. Hemorrhages and lesions in the white line, mainly caused by physical damage, were categorized as WLD. Sole ulcer, also called pododermatitis circumscripta, is a secondary foot disorder and occurs after foot disorders such as SoH and IDHE or after trauma. As in the study by Somers et al. (2003) 'sole ulcer' applies to all ulcers in the sole, toe and heel. Interdigital hyperplasia, commonly referred to as tyloma and fibroma, originates as a reaction to long-lasting inflammation of the interdigital cleft or IDHE. The disorder is recognizable by proliferation of the interdigital skin.

Simulation of cow characteristics

In the model, in each iteration for each cow (i) in the herd, parity (Par_i), milk production (MP_i), lactation value (LV_i), stage of lactation (LS_i) and calving interval (CI_i) were determined. Parity was determined using a discrete distribution function and could have 4 categories (1,2,3, and 4 and higher):

$$Par_i = Discrete([Ppar_1, Ppar_2, Ppar_3, Ppar_{\geq 4}] ,[1,2,3,4])$$

where $Ppar_1$, $Ppar_2$, $Ppar_3$, $Ppar_{\geq 4}$ are the input variables for the probability of having parity 1,2,3, and 4 and higher, respectively. Milk production (MP_i) (kg/305 d) for cow (i) was determined with a Normal Distribution function:

$$MP_{ik} = Normal(MPpar_{ik}, SDMPpar_{ik})$$

where $MPpar_{ik}$ is MP_i in parity (k) and $SDMP_{ik}$ is the standard deviation of MP_i in parity (k).

Given MP_i, for each cow in each month the daily milk yield (kg) is calculated using Wood's lactation curve (Wood, 1967). Using the 0.25 and 0.75 percentiles of MP_i, an LV_i with 3 classes, low-, middle- and high-producing dairy cows, was determined. The LS_i (month after calving) in the first month of the second year was determined, where LS_i can be 1,…,15. A standard calving pattern is used to determine the stage of lactation (LS_i):

$$LS_i = \text{Discrete}([\,P_{LS1},\ldots,P_{LS15}\,]),[(1,\ldots,15])$$

where $P_{LS1},\ldots,P_{LS15}$ are the probabilities for each possible stage of lactation.

Calving interval (CI_i) is determined using a Pert distribution function.

$$CI_i = \text{Pert}\,(CI_{min}, CI_{ml}, CI_{max})$$

Where CI_{min} is the minimum value, CI_{ml} is the most likely and CI_{max} is the maximum value.

Before calving, a cow was assumed to have a dry period of 2 months.

Dynamics of foot disorders

Foot disorder dynamics are modeled according to Figure 1. In the model, in every month each cow had different transition probabilities, depending on the status of the previous month: 1) the probability of getting a foot disorder: probability of change from healthy to subclinical (P_{HS}) or probability of change from healthy to clinical (P_{HC}); 2) the probability of being cured: probability of change from subclinical to healthy (P_{SH}) or probability of change from clinical to healthy (P_{CH}); 3) the probability of a transition from a subclinical foot disorder to a clinical foot disorder (P_{SC}). The subclinical foot disorders had a probability of developing into the clinical phase after one or more months (P_{SC}) or had a probability of cure after foot trimming (P_{SH}). The clinical foot disorders had a certain probability for recovery due to treatment by the farmer, foot trimmer or veterinarian during the year or after foot trimming (P_{CH}) and a probability of culling due to the foot disorder (P_{Cul}). In this study, 2 foot trimming interventions per year were assumed as is the common practice in The Netherlands.

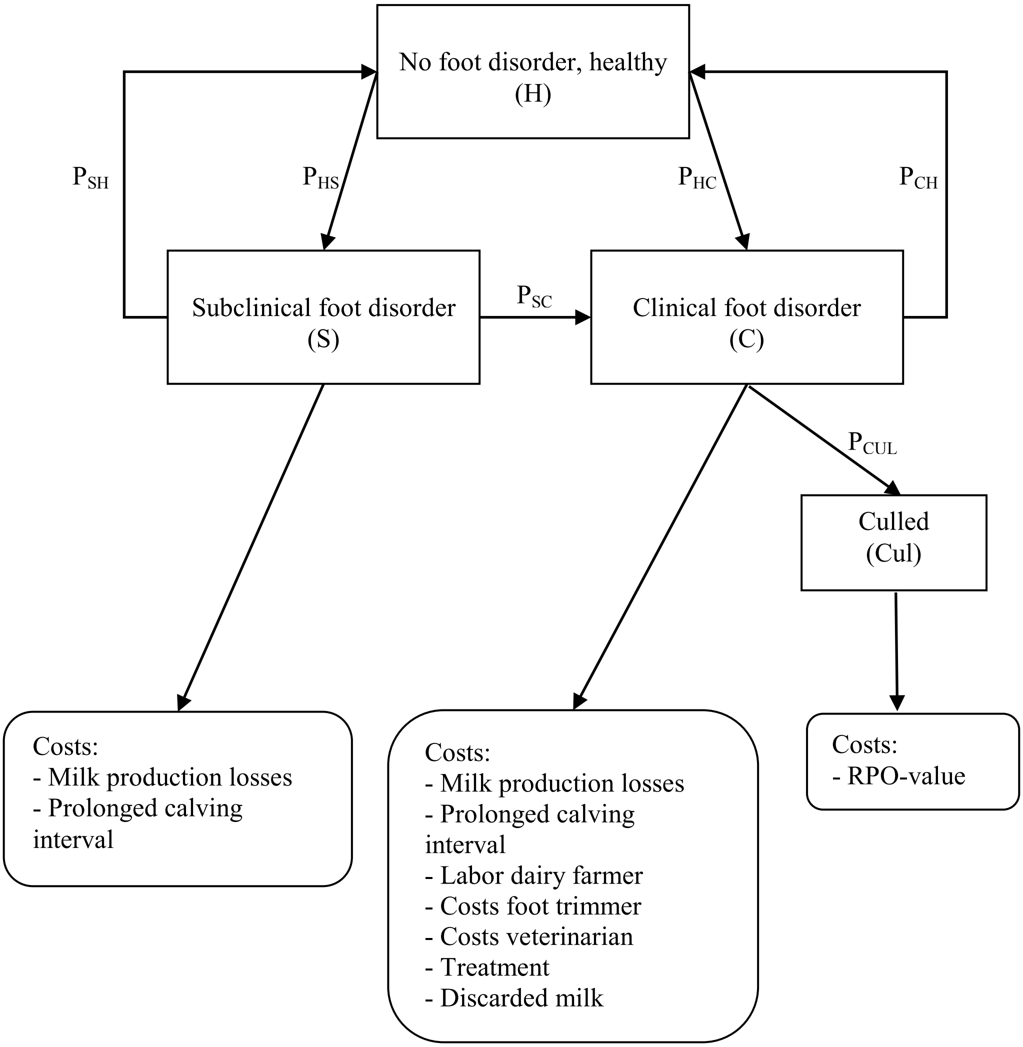

Figure 1. Schematic representation of the dynamics of the foot disorders in the dynamic stochastic simulation model on economic consequences of foot disorders. P_{HS} = probability of change from healthy to subclinical, P_{HC} = probability of change from healthy to clinical, P_{SH} = probability of change from subclinical to healthy, P_{CH} = probability of change from clinical to healthy, P_{SC} = probability of change from transition from a subclinical foot disorder to a clinical foot disorder, P_{CUL} = probability of culling.

For every month (t = 1,…,24), cow (i = 1,…,65) and foot disorder (j = 1,…,7), the state of foot disorder, culled (Cul_{ijt}), clinical (C_{ijt}), subclinical (S_{ijt}) and healthy (H_{ijt}), were determined with a set of discrete distribution functions:

$$Cul_{ijt} = \begin{cases} t = 1 \rightarrow 0 \\ Cul_{ijt-1} = 1 \rightarrow 1 \\ C_{ijt-1} = 1 \rightarrow \text{Discrete}([P_{Cul_{ijt}}, 1 - P_{Cul_{ijt}}],[1,0]) \\ 0 \end{cases}$$

$$C_{ijt} = \begin{cases} t = 1 \rightarrow \text{Discrete}([P_{Cj1}, 1 - P_{Cj1}],[1,0]) \\ Cul_{ijt} = 1 \rightarrow 0 \\ C_{ijt-1} = 1 \rightarrow \text{Discrete}([1 - P_{CHjt}, P_{CHjt}],[1,0]) \\ S_{ij\,t-1} = 1 \rightarrow \text{Discrete}([P_{SCjt}, 1 - P_{SCjt}],[1,0]) \\ H_{ij\,t-1} = 1 \rightarrow \text{Discrete}([P_{HCjt}, 1 - P_{HCjt}],[1,0]) \end{cases}$$

$$S_{ijt} = \begin{cases} t = 1 \rightarrow \text{Discrete}([P_{Sj1}, 1 - P_{Sj1}],[1,0]) \\ Cul_{ijt} = 1 \rightarrow 0 \\ C_{ijt} = 1 \rightarrow 0 \\ H_{ij\,t-1} = 1 \rightarrow \text{Discrete}([P_{HSjt}, 1 - P_{HSjt}],[1,0]) \\ S_{ijt-1} = 1 \rightarrow \text{Discrete}([1 - P_{SHjt}, P_{SHjt}],[1,0]) \\ C_{ij\,t-1} = 1 \rightarrow 0 \end{cases}$$

$$H_{ijt} = \begin{cases} t = 1 \rightarrow \text{Discrete}([P_{Hj1}, 1 - P_{Hj1}],[1,0]) \\ Cul_{ijt} = 1 \rightarrow 0 \\ S_{ijt} = 1 \rightarrow 0 \\ C_{ijt} = 1 \rightarrow 0 \\ 1 \end{cases}$$

where P_{Cj1}, P_{Sj1} and P_{Hj1} are the probabilities for the different foot disorders (j) for t = 1, the first month of the first year. Other probabilities (P_{SC}, P_{SH}, P_{CH}, P_{HS} and P_{HC}) were explained before and varied for the different foot disorders (j).

The probabilities P_{HSij} (j = 1,…,7) and P_{HCij} (j = 1,…,5) are dependent on Par_i, LS_i, LV_i and month (t). For example, a higher producing cow has a higher risk of getting a foot disorder.

P_{Culijt} was adjusted for lactation value and parity; a high-producing cow has less chance of being culled because of a foot disorder than a low-producing cow, and a high-parity cow has more chance of being culled than a young cow (Booth et al., 2004). Subsequently, whether cow (i) had a prolonged calving interval or not is modeled. We assumed that when a foot disorder occurs during the first 4 months after calving, there is the probability of a prolonged calving interval (P_{PCIi}). A prolonged calving interval consists of 21 d. Only one prolongation of the calving interval can take place. P_{PCIi} is given by:

$$P_{PCIi} = \text{Discrete}([P_{PCIi}, 1 - P_{PCIi}],[1,0])$$

Calculation of costs[1]

Total costs due to subclinical foot disorders (TC_{SC}) and total costs due to clinical foot disorders (TC_C) comprised costs for milk production losses (C_{MPLijt}), costs for culling (C_{CULijt}), costs for prolonged calving interval (C_{PCIijt}), costs for labor of the dairy farmer $(C_{LabDFijt})$, costs for the foot trimmer (C_{FTijt}), costs for the veterinarian (C_{Vijt}), costs for treatment (C_{Tijt}), and costs for discarded milk $(C_{Discijt})$. The costs are calculated monthly and summed up to a year for each cow. The costs for milk production losses due to subclinical and clinical foot disorders are based on milk production (MP_i), the percentage of milk production loss (MPL), and costs for milk production losses (C_{MPL}). Costs for a culled cow due to clinical foot disorder were based on the retention pay-off (RPO) value (Houben et al., 1994) and were dependent on Par_i and LV_i. Costs for a prolonged calving interval were calculated by multiplying the number of prolonged days with the costs for each day of prolongation. For clinical foot disorders, the extra labor of the dairy farmer was estimated in hours per month per cow. The costs were calculated by multiplying the hours with the hourly rate of a dairy farmer. Costs for the foot trimmer are calculated on the basis of rates

[1] The model was built and run using values in Euros (€). The values in the published article were converted into US Dollars ($) using an exchange rate of €1 to US $1.41.

per treated cow, and costs for the veterinarian were calculated based on rates per treated cow. The costs for the use of antibiotics, costs for the resulting discarded milk, and topical treatments were included in the model as well. All these different costs were used to calculate the total costs for subclinical (j = 1,…,5) and clinical (j = 1,…,7) foot disorders for a cow (i) during the months (t = 13,…,24). The total costs (TC) due to foot disorders are:

$$TC = TC_{SC} + TC_{C}$$

where

$$TC_{SC} = \sum_{i=1}^{65} \sum_{j=1}^{5} \sum_{t=13}^{24} C_{MPLijt} + C_{PCIijt}$$

and

$$TC_{C} = \sum_{i=1}^{65} \sum_{j=1}^{7} \sum_{t=13}^{24} C_{MPLijt} + C_{CULijt} + C_{PCIijt} + C_{LabDFijt} + C_{FTijt} + C_{Vijt} + C_{Tijt} + C_{Discijt}$$

Default input data

All peer-reviewed papers on prevalence, incidence, and consequences of foot disorders in dairy cattle were analyzed. Only those papers that applied to the criteria for default Dutch dairy circumstances were included. These criteria were cubicle housing system with a concrete (slatted) floor and mainly Holstein dairy cows. Authors' expertise was used when no scientific literature was available.

Cow characteristics. Input on cow characteristics; herd composition, milk production, calving pattern and calving interval are given in Table 1. These inputs were based on data from the Dutch cattle improvement organization (CRV).

Table 1. Default input values for cow characteristics, with their abbreviations and source

Parameter	Abbreviation	Value (SD)	Source
Farm size	N	65	CRV, http://www.cr-delta.nl
Distribution parities			CRV, http://www.cr-delta.nl
Parity 1	$Ppar_1$	0.32	
Parity 2	$Ppar_2$	0.25	
Parity 3	$Ppar_3$	0.18	
Parity 4 and more	$Ppar_{\geq 4}$	0.25	
Mean milk production, kg/yr			CRV
Parity 1	MP1	7,434 (437)	
Parity 2	MP2	8,666 (510)	
Parity 3	MP3	9,201 (541)	
Parity 4 and more	MP4	9,156 (539)	
Calving interval, d	CI	415	CRV, http://www.cr-delta.nl

Dynamics of foot disorders. Data on prevalence during foot trimming after summer and winter, scored by researchers, were used as the basis for the input into the model (Somers et al., 2003). These data relate to cubicle housing systems with a concrete (slatted) floor, pasturing during summer, and 2 foot trimming interventions per year. Prevalence was adjusted for a cow having one foot disorder at a time, because additive calculation of the costs overestimates them and the interdependence of the different foot disorders is not known exactly enough to correct for this overestimation. Foot disorders were classified as clinical and subclinical foot disorders. This classification was based on locomotion scores before and after foot trimming (Frankena et al., 2009) combined with information on pathology of different foot disorders (e.g., Somers et al. 2003). By using prevalence data on lame cows (using locomotion scores) we avoided overestimation of lameness. The locomotion scores before and after foot trimming were compared to estimate the cure rates after foot trimming. The different transition probabilities - transition from subclinical to clinical, cure of clinical foot disorders during the year and probability of getting a new foot disorder - were based on the scientific literature and the authors' expertise (Table 2). For the foot disorders having a subclinical and clinical state, it was assumed that the foot disorder first occurred as a subclinical foot disorder before transition to a clinical foot disorder.

All cases of IP and SUL were assumed to be clinical foot disorders. It was assumed that IP was (almost) always treated with antibiotics soon after a farmer identified a cow with IP and that treatment resulted in cure. Sole hemorrhages were scored based on the study by Somers et al. (2003), who scored the hemorrhages on density and extent of the hemorrhage. Slightly red discoloration, stripes or small spots, and moderate hemorrhage made up the subclinical cases. Severe hemorrhages, extended and acute red discoloration counted for the clinical cases of SoH in the model.

Table 2. Default input probabilities (%), with their abbreviations, for the dynamics of foot disorders (FD) for the default farm (cubicle housing with concrete (slatted) floor, pasturing during summer (April through September), two foot trimming interventions per year (in April and October)

Input variable	Abbreviation	Probabilities, %						
		IP	IDHE	DD	SoH	WLD	SUL	HYP
Probabilities at t=1(starting month in the model)								
Clinical FD	P_{C}[1]	0.4	-	-	-	-	1.5	-
Subclinical FD	P_{SC}[1]	-	16.4	7.6	21	3.3	-	1.7
Transition probabilities:								
Subclinical FD from healthy state	P_{HS}[1]							
Summer		-	0.67	1.63	2.61	0.47	-	0.30
Winter		-	3.92	2.45	3.28	0.53	-	0.23
Clinical FD from healthy state	P_{HC}[1]							
Summer		0.52	-	-	-	-	0.55	-
Winter		0.52	-	-	-	-	0.58	-
Clinical FD from subclinical FD	P_{SC}[1]							
Summer		-	5	20	7.5	10	-	10
Winter		-	10	30	7.5	10	-	10
Cure[4] of subclinical FD in months April and October	P_{SH}[1]	-	60[2]	30	60	50	-	50
Cure[4] of clinical FD	P_{CH}[1]							
In months April and October		98	60[2]	30	60	50	75	50
In months May-September and November-March		98	10	20	10	20	20	10
Culling	P_{CUL}[3]	4	4	4	4	4	4	4

IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia. It is assumed that IP and SUL only occur as clinical foot disorder, the other foot disorders (DD, IDHE, SoH, WLD and HYP), first occur as a subclinical foot disorder before transition to a clinical foot disorder occurs.

[1]Probabilities are estimated based on literature (Somers et al., 2003, 2005a,b; Holzhauer et al., 2006; Holzhauer et al., 2008; Frankena et al., 2009) and the authors' expertise.

[2]The probability of cure rate after pasturing is 50%.

[3]Applying to all clinical foot disorders based on Whitaker et al. (2004).

[4]Cure can occur as a result of treatment by a farmer, as a result of foot trimming or after treatment by a veterinarian.

The division between clinical and subclinical lesions of DD and IDHE was based on the literature (Somers et al., 2003; Somers et al., 2005a,b; Holzhauer et al., 2006). Digital dermatitis thus follows the classification by Döpfer et al. (1997). The severity of IDHE was graded from 0 to 4, where grade 4 and partly gradation 3 were responsible for the lame and tender walking of cows in the model (Frankena et al., 2009). Based on the study by Somers et al. (2003) the early stage of WLD, white line separation, was classified as a subclinical foot disorder. The advanced stage of WLD, the white line abscess (when a white line separation has progressed to the level of the corium resulting in abscess formation) was assumed to cause lameness. The probability for a cow to be culled (P_{CUL}) due to clinical foot disorders was 4% (adjusted after Whitaker et al., 2004). Culling due to subclinical foot disorders was not included in the model. Such culling is related to, for example, a prolonged calving interval, not to the foot disorder itself. In the values derived from Inchaisri et al. (2010), which we used for estimation of costs due to prolonged calving interval, culling was already included. Dairy cows with clinical foot disorders, on average, have a calving interval prolonged by 12 d (Fourichon et al., 2000). The probability for having an extra cycle (21 d) in the model, therefore, is estimated to be 60%. Subclinical foot disorders have less impact on calving interval; the probability of having an extra cycle due to a subclinical foot disorder is estimated to be 20% (Bicalho et al., 2007b).

Calculation of costs. The estimates of milk production losses were based on the literature, which shows that high milk production and lameness are related. The references we used for our input estimates account for the fact that dairy cows with higher production have a higher risk for having foot disorders. The time a dairy farmer spends for treatment of a lame cow, and the probabilities of treatment by dairy farmer, foot trimmer and veterinarian were based on the authors' expertise (Table 3). Costs for milk production losses and discarded milk were estimated for the milk quota circumstances prevailing in The Netherlands (Huijps and Hogeveen, 2007). The value for a culled cow is dependent on parity and lactation value. The costs for prolonged calving interval were estimated to be €0.70 per extra day, derived from (Inchaisri et al., 2010). The hourly rate for a dairy farmer, costs for a foot trimmer, and costs for a veterinarian were derived from the authors' expertise and Dutch standard values (KWIN-V, 2008-2009). Costs for topical treatment were based on the authors' expertise. It was assumed that only IP is treated with antibiotics, and that such treatment results in some days of withholding time for the milk (Table 4) .

Table 3. Default input values, with their abbreviations and source, for calculating the costs due to the different foot disorders (FD)

		Values							
Input variable	Abbreviation	IP	IDHE	DD	SoH	WLD	SUL	HYP	Source
Milk Production Losses, %/mo	MPL								Amory et al. (2008); Bicalho et al.
Clinical FD		8	8	8	8	8	8	8	(2008); Green et al. (2002);
Subclinical FD		-	3	3	3	3	-	3	Warnick et al. (2001)
Probability prolonged calving interval, %	P_{PCI}								Bicalho et al., 2007b
Subclinical FD		20	20	20	20	20	20	20	
Clinical FD		60	60	60	60	60	60	60	
Extra labor dairy farmer, h/mo	E_{LabDF}	0.5	0.5	0.5	0.5	0.5	1	0.5	authors' expertise
Probability extra labor dairy farmer, %	P_{LabDF}	100	20	67	20	40	50	20	authors' expertise
Probability extra treatment foot trimmer, %	P_{FT}	0	5	10	5	10	40	5	authors' expertise
Probability extra visit veterinarian, %	P_V	5	1	1	1	1	5	1	authors' expertise

IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia.

Table 4. Default input values, with their abbreviation and source, for calculating the costs due to the different foot disorders

Input variable	Abbreviation	Value	Source
Costs for milk production losses, €/kg	C_{MPL}	0.12	Huijps and Hogeveen (2007)
Costs for discarded milk, €/kg	C_{Disc}	0.17	Huijps and Hogeveen (2007)
Culling costs, €/cow	C_{CUL}	min. 240 max. 913	Van der Walle (2004) using method of Houben et al. (1994)
Costs prolonged calving interval, €/d	C_{PCI}	0.7	Inchaisri et al. (2010)
Hourly rate dairy farmer, €/h	Hr_{DF}	20	Personal communication, Agricultural Farm Service (AB Oost, Almen, The Netherlands)
Extra costs foot trimmer, €/cow	C_{FT}	26	KWIN-V (2008-2009)
Extra costs veterinarian, €/visit/cow	C_V	85[1]	Authors' expertise
Costs treatment, €/treatment	C_T		Authors' expertise
Antibiotics IP		6	
Local treatment		0.4[2]	

[1]For interdigital phlegmon (IP) there are only visit costs, estimated to be €30, the visits for the other foot disorders also include labor of the veterinarian.
[2]Higher for sole ulcer (SUL) and digital dermatitis (DD) because of repeated cases and use of blocks for SUL.

Sensitivity analysis

A sensitivity analysis was performed to assess the effect of varying the input parameters on the total costs of foot disorders for our default farm. The sensitivity analysis was performed by adjusting the default values of selected parameters (Tables 1, 2, 3, and 4) to realistic alternatives, as described herein. The probabilities of getting a foot disorder (P_{HS} and P_{HC}) were increased and decreased by 50%; the probability of transition to a clinical foot disorder from a subclinical foot disorder (P_{SC}) was increased by 50%. The probability of cure (P_{SH} and P_{CH}) on foot trimming were increased and decreased by 25% and P_{CH} during the year was increased by 10 percentage points. The probability of culling (P_{CUL}) was doubled. The probability of prolonged calving interval (P_{PCI}) for clinical foot disorders was increased to 70% and for subclinical foot disorders to 30%. The costs of prolonged calving interval (C_{PCI}) per day were decreased to €0.50 /d and increased to €1.00 /d.

Milk production losses (MPL) were adjusted in 3 ways. MPL for the subclinical foot disorders were decreased to 1.5%. MPL for the clinical foot disorders were decreased to 6%. MPL for the clinical claw lesions (SoH C, SUL and WLD C) were increased to 12% (Amory et al., 2008). The costs for milk production losses (C_{MPL}) were increased to €0.24 (for a non-quota situation) and €0.07 (for an extensive dairy farm under a quota situation). The extra labor of the dairy farmer (E_{LabDF}) was increased by half an hour per month for every foot disorder, the probability of extra labor for the dairy farmer (P_{LabDF}) was increased by 10 percentage points, the hourly rate for the dairy farmer (Hr_{DF}) was decreased and increased by €10. The probability of extra costs for a foot trimmer (P_{FT}) were increased by 5 percentage points for all foot disorders, the costs for a foot trimmer (C_{FT}) were increased to €38 per treatment. The probability of an extra visit of a veterinarian (P_V) was increased by 5 percentage points, and the costs for a visit of a veterinarian (C_V) were increased by €10. Herd composition was changed by having a higher proportion older cows (parity ≥4). The average 305 d production per cow was increased by 1,000 kg/305 d.

Results

Default

After running the model, the results showed that throughout the year the prevalence of foot disorders varied from 43% after foot trimming in October (after grazing) to 80% at the end of the winter in March (before foot trimming; Figure 2). The prevalence of foot disorders per month showed there is a clear effect of pasturing during summer and the foot trimming interventions on the prevalence of foot disorders. The prevalence of the foot disorders was highest at the end of the winter period. Figure 2 gives a graphical presentation of all foot disorders during the year. Subclinical SoH had the highest prevalence; SoH and IDHE were mainly subclinical, and only a few cases become clinical. This was also the case for the less prevalent foot disorders, WLD and HYP. The foot disorders IP and SUL had relatively low total prevalence, but did account for a substantial part of the total prevalence of clinical foot disorders. The foot disorder SoH had the most cases per year and had the longest duration (Table 5). Digital dermatitis had most cases that became clinical. The more severe foot disorders IP and SUL had a relative short duration, but were responsible for 28% of all clinical cases. The total costs due to foot disorders for a farm with 65 cows in the default situation are €3,474 per year (€53 per cow) with a range between €2,282 and €4,965. The costs due to subclinical foot disorders were €1,107 per year (range between €883 and €1,367), which is 32% of the total costs due to foot disorders (Table 6). On average a clinical case costs €67 and a subclinical case €13. Milk production losses caused 44% of the total costs due to foot disorders, culling 22%, prolonged calving interval 12% and costs for extra labor of the dairy farmer 12%. Interdigital phlegmon and SUL caused 23% of the total costs due to foot disorders (Table 7). Digital dermatitis had the greatest costs, mainly because of the relatively high incidence of the clinical stage. For SoH and IDHE, the subclinical stage had the highest cost.

Sensitivity analysis

Sensitivity analysis showed that variables concerning milk production are important for the economic costs due to foot disorders. Total costs due to foot disorders on the default farm were most sensitive for variation in costs for milk production losses and discarded milk.

Increased costs for milk production losses (€0.24) resulted in an increase of the total costs per year to €5,096. Decreased costs for milk production losses (€0.07) resulted in a decrease of the total costs per year to €2,746. Production level and percentage of milk production losses for the different foot disorders were also important. Furthermore, the transition probabilities of the foot disorders were important. Probabilities of getting a foot disorder (P_{HS} and P_{HC}) resulted, with increased probability, in total costs of €4,786 per year and, with decreased probability, in total costs of €1,986 per year. Probabilities of cure (P_{SH} and P_{CH}) resulted, with increased probability, in total costs of €2,847 per year and, with decreased probability, in total costs of €4,162 per year. These variables, the probabilities of getting a foot disorder and cure of a foot disorder, determined the incidence and duration of the foot disorders. Variables with little effect (<5%) are not shown (Figure 3).

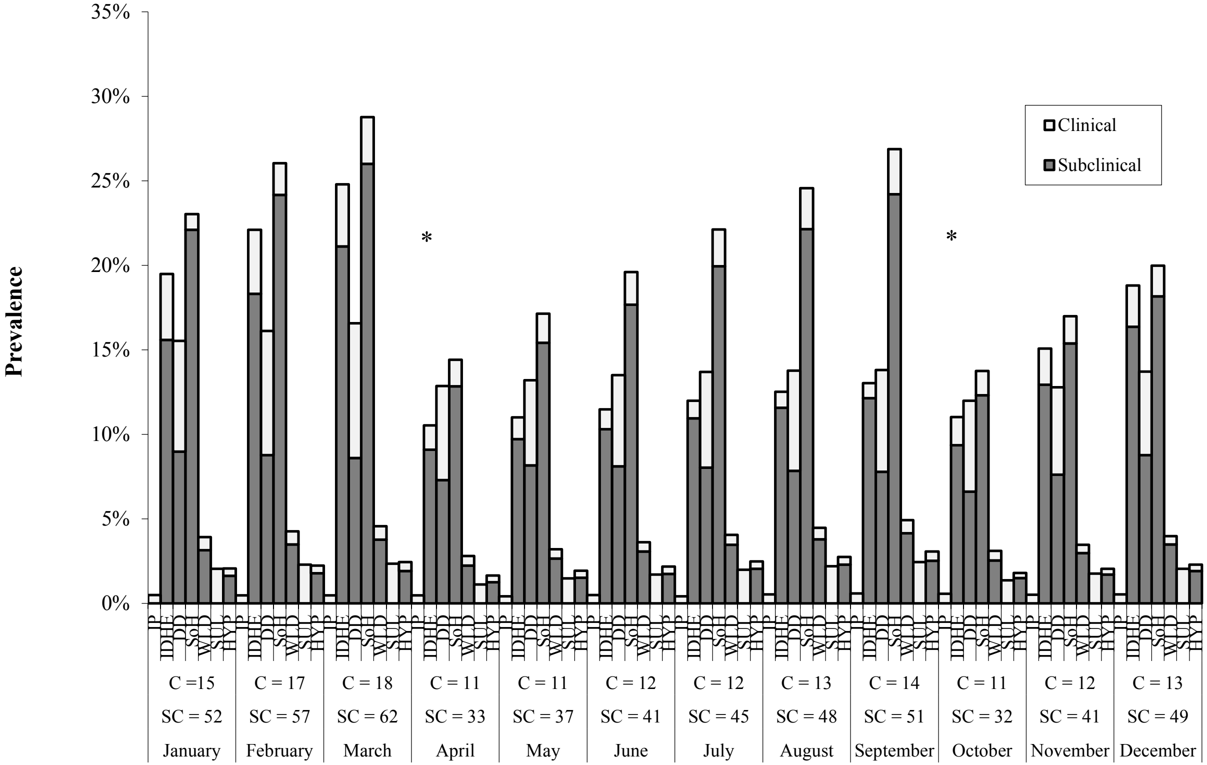

Figure 2. Average monthly prevalence of the different foot disorders, both subclinical (SC, dark bars) and clinical (C, light bars), on the default farm (cubicle housing with concrete (slatted) floor, pasturing during summer (April through September), two foot trimming interventions per year (in April and October)). The months in which the foot trimming interventions take place (in April after housing and in October after pasturing) are marked by *. Prevalence of subclinical and clinical foot disorders in these months represents the situation as measured after foot trimming. The following abbreviations have been used: SC = the total prevalence of subclinical foot disorders in a month, C = the total prevalence of clinical foot disorders in a month, IP = interdigital phlegmon, SUL = sole ulcer, SoH = sole hemorrhage, DD = digital dermatitis, IDHE = interdigital dermatitis and heel erosion, WLD = white line disease, HYP = interdigital hyperplasia.

Table 5. Incidence, cases/100 cows/year, of subclinical (SC) or clinical (C) foot disorders, and duration per case for the different foot disorders on the default farm (cubicle housing with concrete (slatted) floor, pasturing during summer (April through September), two foot trimming interventions per year (in April and October)), with 0.05 and 0.95 percentiles in parentheses

		IP	IDHE	DD	SoH	WLD	SUL	HYP
Incidence, cases/100 cows/yr	SC	-	37	27	54	9	-	5
			(26;49)	(18;35)	(42;66)	(5;15)		(2;9)
	C	6	7	20	7	3	9	2
		(2;11)	(3;12)	(12;28)	(2;12)	(0;6)	(3;15)	(0;5)
Duration, mo	SC	-	4.28	3.65	4.43	4.43	-	4.27
			(3.10;5.52)	(2.68;4.78)	(3.55;5.27)	(2.50;6.42)		(2.00;7.25)
	C	1.02	3.40	3.54	3.38	2.90	2.50	4.01
		(1.00;1.15)	(1.63;5.75)	(2.38;5.00)	(1.00;6.25)	(1.00;6.33)	(1.37;4.00)	(1.00;10.00)

IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia.

Table 6. Economic consequences (€/yr; 0.05 and 0.95 percentiles in parentheses) of subclinical (SC) and clinical (C) foot disorders on the default farm (cubicle housing with concrete (slatted) floor, pasturing during summer (April through September), two foot trimming interventions per year (in April and October)) classified by cost factors

	SC	C	Total
Costs milk production losses (C_{MPL})	864	673	1,537
	(705;1,042)	(454;957)	(1,226;1,869)
Costs culling (C_{CUL})	0	769	769
	(0;0)	(0;2,106)	(0;2,106)
Costs prolonged calving interval (C_{PCI})	243	175	418
	(147;338)	(103;265)	(294;544)
Costs extra labor dairy farmer (C_{LabDF})	0	410	410
	(0;0)	(250;590)	(250;590)
Costs extra visit foot trimmer (C_{FT})	0	105	105
	(0;0)	(26;208)	(26;208)
Costs extra visit veterinarian (C_V)	0	53	53
	(0;0)	(0;170)	(0;170)
Costs treatment (C_T)	0	48	48
	(0;0)	(29;68)	(29;68)
Costs for discarded milk (C_{Disc})	0	135	135
	(0;0)	(28;267)	(28;267)
Total costs (TC)	1,107	2,367	3,474
	(883;1,367)	(1,231;3,855)	(2,282;4,965)

Table 7. Economic consequences (€/yr; 0.05 and 0.95 percentiles in parentheses) for the different foot disorders, both subclinical (SC) and clinical (C) on the default farm (cubicle housing with concrete (slatted) floor, pasturing during summer (April through September), two foot trimming interventions per year (in April and October)), classified by foot disorders

	IP	IDHE	DD	SoH	WLD	SUL	HYP
SC	-	313	191	473	83	-	48
		(183;447)	(98;285)	(328;638)	(20;168)		(3;118)
C	339	272	886	237	113	455	66
	(63;933)	(29;959)	(347;1,760)	(21;874)	(0;633)	(99;1,152)	(0;245)
Total	339	585	1,076	710	195	455	114
	(63;933)	(281;1,289)	(518;1,975)	(426;1,401)	(38;725)	(99;1,152)	(6;318)

IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia.

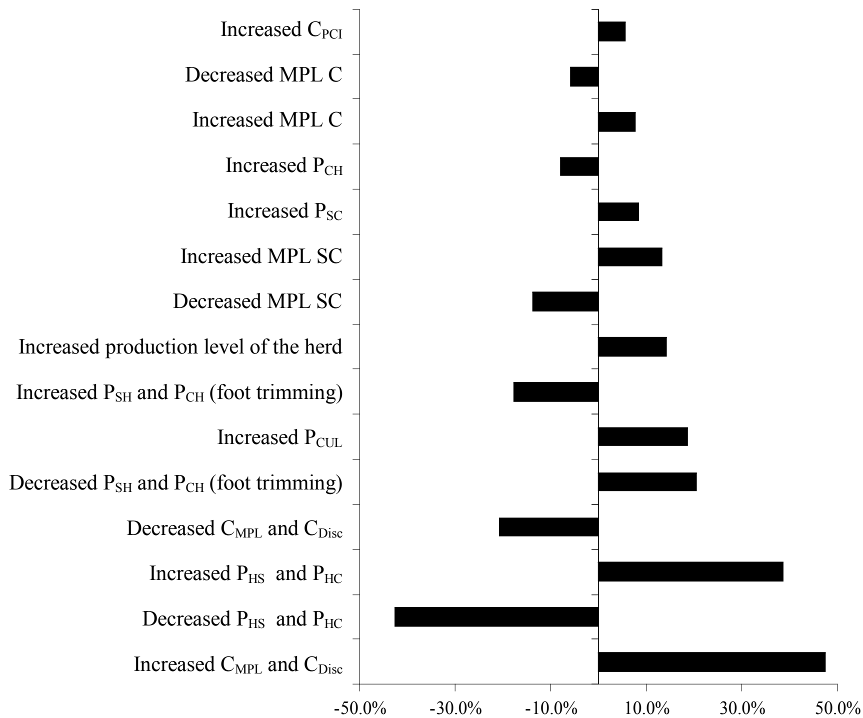

Figure 3. Most important results from the sensitivity analysis, showing the positive or negative effect of the changed variables on the costs due to foot disorders (%). C_{MPL} = costs milk production losses, C_{Disc} = costs discarded milk, P_{HS} = probability of change from healthy to subclinical, P_{HC} = probability of change from healthy to clinical, P_{SH} = probability of change from subclinical to healthy, P_{CH} = probability of change from clinical to healthy, P_{CUL} = probability of culling , MPL SC = Milk production losses subclinical foot disorders, MPL C = Milk production losses clinical foot disorders, P_{SC} = probability of change from transition from a subclinical foot disorder to a clinical foot disorder, P_{CUL} = probability of culling, C_{PCI} = costs prolonged calving interval.

Discussion

The dynamic stochastic Monte Carlo simulation model presented in this study adds much to existing model calculations because this model gives the opportunity to simulate the dynamics of different foot disorders, both clinical and subclinical. Previous economic studies were model-based as well, but were less specific, not taking into account subclinical foot disorders and the dynamics of different foot disorders (Enting et al., 1997; Kossaibati and Esslemont, 1997). In our model, economic consequences of foot disorders can be estimated, both clinical and subclinical, and for the different types of foot disorder. The model can be used for a variety of circumstances and different countries. The default input used in our model relates to farms with cubicle housing systems with a concrete (slatted) floor, mainly Holstein dairy cows, pasturing during summer, and 2 foot trimming interventions per year. In case of doubt for input estimations or use of authors' expertise we used conservative estimates to avoid overestimation.

In simulation modeling estimates for input values are important. In our study, the literature was not always available that provided all the input values needed. Therefore, we needed to estimate input values as accurately as possible, based on the available literature and expertise. Using the outcomes from the available studies, we estimated the input as realistic as possible.

The results from the model show that the prevalence of all foot disorders (43% to 80%) corresponded to the prevalence found in Dutch studies (e.g., Somers et al., 2003). This validates the estimated input values for input parameters on the dynamics of the different foot disorders which we could not derive directly from literature. The prevalence of clinical foot disorders (11% to 18%) is lower compared to that cited in the literature (Bicalho et al., 2007b; Frankena et al., 2009). The effects of pasturing and the foot trimming interventions were visible in the prevalence of the foot disorders (Figure 2). The prevalence of foot disorders increased more during winter (when cows are housed in cubicles) than during summer (when cows are pastured). When there are fewer subclinical foot disorders (due to foot trimming and pasturing) there will be fewer transitions to clinical foot disorders (preventive effect of foot trimming and pasturing). This was assumed for the foot disorders IDHE, DD, SoH, WLD and HYP, which first occur subclinical and then may become clinical. The effect of foot trimming on clinical foot disorders was less obvious than on subclinical foot disorders. An explanation for this is that clinical foot disorders are treated throughout the year, which is not the case for subclinical foot disorders. The incidence of 54% for all clinical foot disorders in our model, which corresponds to the incidence found in the study of Clarkson et al. (1996), is lower than the incidence found in the study of Hedges et al. (2001) (69%), and is higher than the incidence found in the studies of Warnick et al. (2001) and Bicalho et al. (2008). Differences in prevalence and incidence for the different clinical and subclinical foot disorders among different studies can be due to the subjective assessment of what is clinical and subclinical, and what is severely lame and (merely) lame, and how different foot disorders are defined and assessed. Several studies with low incidence would underestimate the real incidence. Studies with low incidence are mainly based on farmer assessment or interval assessment by a veterinarian or a foot trimmer. Differences among different studies also exist because there is large variation between farms, farming systems, regions and countries.

The total costs due to foot disorders for the default farm with 65 cows were €3,474 per year - a total cost of €53 per cow. Total costs at the herd level varied between €2,282 and €4,965. The subclinical foot disorders accounted for 32% of these costs. In the model the costs for the 2 foot trimming interventions were not taken into account (€10 per cow per year). Foot trimming is partly preventive (reducing costs due to foot disorders by prevention of new subclinical foot disorders and prevention of transition of subclinical to clinical foot disorders) and partly curative (direct costs for the cure of subclinical and clinical foot disorders). Taking into account the curative costs, the total costs due to foot disorders on the default farm increased by approximately €5 per cow per year. This increase results in a total cost of €58 per cow. The foot trimming interventions, performed by qualified, trained foot trimmers, have a great influence on the prevalence of foot disorders (Figure 2). A positive effect of foot trimming is also indicated by Sogstad et al. (2007) where milk production increased after foot trimming. Without foot trimming interventions, the prevalence of foot disorders, subclinical and clinical, would be higher (Manske et al., 2002). A higher prevalence of foot disorders results in more costs due to these foot disorders. For example, there would be more costs for culling due to higher prevalence of clinical foot disorders.

After mastitis, which costs €78 per average cow in the herd (Huijps et al., 2008), foot disorders cause substantial costs for the dairy farmer. Results from an earlier Dutch study gave €23 per average cow in the herd for lameness (Enting et al., 1997). The calculation of these costs did not take into account the costs due to subclinical foot disorders and the dynamics of various foot disorders. Furthermore, a low level of production losses was found. The new calculation in our study implies that the costs due to foot disorders are more substantial than farmers might think. However, compared with the results of Kossaibati and Esslemont (1997) the costs found in our study are lower. In that study it was assumed, for example, that SUL involved higher milk production losses, higher risk of culling, a longer calving interval and a higher prevalence compared with other foot disorders. In our study, there was no differentiation in milk production losses, risk of culling or calving interval for the different foot disorders, because there is no scientific literature available to make this input specific for the different foot disorders. In our model, therefore, there was no distinction between the infectious and the physical foot disorders for milk production losses. Information on this is ambiguous (Warnick et al., 2001; Green et al., 2002; Amory et al., 2008). A better estimation of the economic consequences of foot disorders requires more specific information about the effects of the different foot disorders on, for example, milk production losses and culling decisions. The effects of different gradations of foot disorders and the effects of foot disorders before and after diagnosis and treatment are also required for a better estimation of their economic consequences. The effects of foot disorders differ among cows, farms, and countries, and development of foot disorders differs between cows. In one cow, for example, a foot disorder progresses faster than in another cow. Differences between farms originate in the varied management practices of the farmer. Detection and treatment of foot disorders by farmers vary according to the attitude of the farmer. Some farmers, for example, will detect a cow with foot disorder earlier and treat the cow more precisely than other farmers. Regulations concerning treatment differ between countries and influence the timing and the precision of treatment. Treatment by a veterinarian is, for example, compulsory and subsidized in certain countries. These differences have great influence on the above mentioned effects of foot disorders. Our model can be adjusted for these specific circumstances. Modeling specific circumstances in dairy husbandry, using specific input values, will be valuable.

Studies on the relationship between the prevalence of different foot disorders at any one time are available (e.g., Holzhauer et al., 2006; Capion et al., 2008). However, these data are not precise enough to use in this model. Therefore relationships between foot disorders were not modeled and it was assumed that a cow could only have one foot disorder at a time. This assumption has limited impact on the calculated costs, because the prevalence of two foot disorders at the same time does not cause twice as much in terms of production losses or a doubled probability of culling or a doubly prolonged calving interval.

In our study, foot disorders were classified as subclinical or clinical based on experimental assessment (Manson and Leaver, 1988; Bicalho et al., 2007a). Obviously lame cows and cows walking tenderly were considered lame cases. As the literature shows, dairy farmers do detect lameness less frequently than do researchers (Espejo et al., 2006). However, the costs due to foot disorders that are present without treatment or detection by the farmer are considerable. This finding implies that farmers might underestimate the benefits of taking action earlier and more thoroughly. Greater effort by the farmer in an early stage could, at minimum, prevent production losses, reduce probability of culling and result in less effect on the calving interval of dairy cows. This observation is supported by the results from the sensitivity analysis, which showed that the prevalence and incidence of foot disorders, determined by P_{HS}, P_{HC}, P_{SH} and P_{CH}, have considerable impact on the costs due to foot disorders. The accuracy of the estimation of the costs due to foot disorders will improve with more information on 1) lameness detection specific to the different foot disorders; 2) the percentage of farmers who will take action at certain degrees of severity of different foot disorders; 3) how quickly farmers will take action; and 4) the resulting cure rates and recovery times.

The information on the costs due to foot disorders can increase the awareness of dairy farmers with respect to the foot disorders as a health and welfare problem in dairy cattle. More awareness could stimulate an increase of quality and frequency of taking measures to reduce the prevalence of foot disorders. This will be beneficial for the dairy farmer in economic terms and for the dairy cow in terms of health and welfare.

Conclusions

The dynamic stochastic Monte Carlo simulation model developed in this study gives an estimation of the economic consequences of foot disorders in dairy cattle, applicable for varying situations. Total costs due to foot disorders on the default farm under Dutch circumstances with 65 cows were €3,474 per year (€53 per cow), varying from €2,282 to €4,965. This calculation implies that the costs due to foot disorders are more substantial than farmers might think. Subclinical foot disorders caused 32% of the total costs due to foot disorders. Costs due to foot disorders that are present without treatment or detection by the farmer are considerable. This finding implies that farmers might underestimate the benefits of taking action earlier and more thoroughly. This study showed that, besides milk production losses, costs for milk production losses and costs for discarded milk, the incidence of the foot disorders, and the probability of cure have a great impact on the economic consequences of such foot disorders. More awareness and more thorough action by farmers concerning dairy cow foot health could reduce the economic consequences and improve health and welfare.

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Chapter 3

Assessing the welfare impact of foot disorders in dairy cattle by a modeling approach

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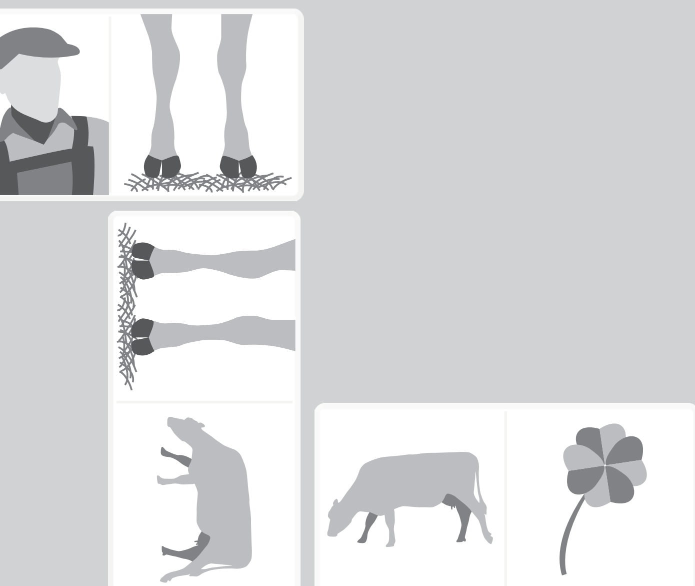

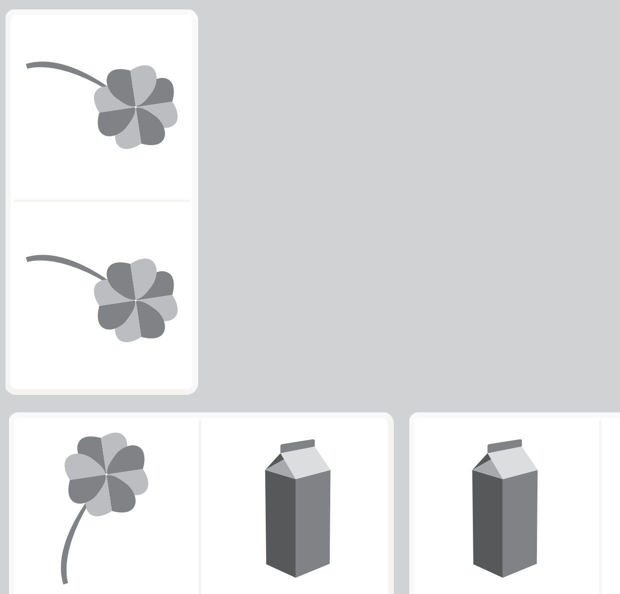

Abstract

Foot disorders are the main cause of dairy cow lameness and are considered to have a major impact on the welfare of dairy cattle. This study adopts a modeling approach, using a dynamic stochastic model, to provide more insight in the welfare impact of different types of foot disorders, both clinical and subclinical. The impact of specific foot disorders on welfare was assessed by simulating the incidence and duration of foot disorders and the pain associated with them. Pain assessment was based on locomotion scores, with underlying knowledge obtained from scientific literature and experts. The results demonstrated the seriousness of the welfare impact of foot disorders. The negative welfare impact was measured on a scale from 0 through 60, where the maximum outcome represents a cow having very severe pain during the whole year. On average, each cow achieves a welfare impact score of 12 which is 20% of the maximum welfare impact score. This welfare score equals having severe pain for a period of three months, indicating a serious impact on welfare. On average, digital dermatitis (DD) impacts most on welfare, which is caused by a high incidence of the painful clinical stage, followed by sole hemorrhages (SoH) and interdigital dermatitis and heel horn erosion (IDHE). The combination of a high incidence and long duration of SoH and IDHE causes this relatively high welfare impact of foot disorders that occur mostly subclinical. On average, over 1 year, 46% of the welfare impact due to foot disorders is caused by clinical foot disorders. The fact that subclinical foot disorders contribute more or less equally to the effects on welfare as clinical ones, indicates that farmers may readily underestimate the welfare impact by a factor two. Modeling welfare impact at cow level, individual cases of foot disorders, stresses the importance of pain intensity, indicating the importance of clinical foot disorders. This study demonstrated the serious welfare impact of foot disorders in dairy cattle and pointed out the considerable impact of subclinical foot disorders. Furthermore, the approach of welfare assessment, for example herd v. cow level, influenced the ranking of foot disorders for their impact on animal welfare. Potentially, this leads to different prioritization of specific solution strategies for dairy farmers, e.g., focusing on cow comfort, hygiene or preventive medical treatments, foot trimming and / or health monitoring. The findings in this study support in raising awareness about this welfare issue.

Key words: dairy cow, foot disorder, modeling, welfare impact

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Introduction

Foot disorders, which are the main causes of dairy cow lameness, are considered to have a major impact on the welfare of dairy cattle (Galindo and Broom, 2002; Algers et al., 2009), and cause economic losses for the dairy farmer (Bruijnis et al., 2010). These consequences are mainly because of the pain caused by foot disorders, which likely affects the locomotion of the cow (Flower and Weary, 2009). Pain also has a direct negative effect on the affective state of the cow and causes indirect negative effects by obstructing the performance of cow-specific behavior, as cows may be reluctant to show it because of their stoic nature as a prey animal (O' Callaghan et al., 2003; Algers et al., 2009). The performance of species-specific behaviors is assumed to be rewarding in itself or helps to fulfill physiological needs and allows an animal to live according to its nature (Broom, 1996; Dawkins, 2003). A dairy cow has a wide range of cow-specific needs (Algers et al., 2009), of which some are specifically influenced by the presence of foot disorders, such as the ability to rest, to exercise and move freely, to feed and drink, etc. (e.g., Walker et al., 2008). Impaired functioning due to foot disorders may manifest as lower milk production (Onyiro et al., 2008), resulting from lower feed intake (Bach et al., 2007), or as reduced fertility (Bicalho et al., 2007).

Approximately 80% of the dairy cows have one or more foot disorders (Somers et al., 2003) and about a third of these cows is visibly lame (Frankena et al., 2009). The incidence of lameness is reported to be over 50% (Hedges et al., 2001). Preventive strategies and therapeutic treatments are available, but dairy farmers may not put these measures into action (Bell et al., 2009) as they tend to underestimate the problem (Whay et al., 2002). This is problematic, as the role of dairy farmers is crucial in improving dairy cow welfare through the prevention and treatment of foot disorders. More insight into the consequences of foot disorders is likely to increase commitment in combating foot disorders. An important consequence of foot disorders is the impact on economics, as is shown by Bruijnis et al. (2010), as well as the consequences for welfare of the dairy cow. The impact on dairy cow welfare depends on the severity, duration and incidence of the foot disorders and these characteristics are specific for each foot disorder. Some foot disorders, such as interdigital dermatitis and heel horn erosion, occur mainly subclinical. Often such foot disorders are not diagnosed and treated and, consequently, develop in a long-lasting and clinical foot disorder. In contrast, interdigital phlegmon (IP) is very acute and painful. Typically, this foot disorder is treated accurately with antibiotics as it is easy to diagnose and the farmer is aware of the negative consequences (arthritis) when IP is not treated. Differences in welfare impact can be revealed by using different ways of welfare assessment, like welfare assessment on individual cow level or on herd level.

The present study adopts a modeling approach to provide more insight into the welfare impact of different foot disorders, both clinical and subclinical. Existing knowledge, obtained from literature and experts, is used in a dynamic simulation model in order to establish transparency on welfare impact of different foot disorders.

Material and methods

Conceptual framework

The following issues will be addressed before the model is described in this Materials and methods section: i) the adopted view on animal welfare, ii) the way to assess the impact of foot disorders on animal welfare, iii) a short description of the seven different foot disorders distinguished in our study.

Animal welfare. Animal welfare has been defined from a diversity of views and in this study the one of Fraser et al. (1997) is adopted. In this view three different aspects are combined: biological functioning (functioning, health, growth); feelings of the animal (affective state; feel well; minimize suffering); natural living (through the development and use of natural adaptations). Farmers tend to interpret animal welfare on the basis of biological functioning and are confident that providing care and assuring health leads to good animal welfare (De Greef et al., 2006). Over the years, in Western societies, increasingly more value has been given to the feelings of the animal, as related to efforts made to cope with environmental challenges or the fulfillment of behavioral needs. The aspect of feeling is often addressed by animal scientists, for example, by recording behavior (Dawkins, 1980) or physiological parameters (Broom, 2007). The third aspect of animal welfare, that is, natural living, seems highly valued nowadays. Natural living relates to how well the animal is able to perform species-specific behaviors and fulfill species-specific needs (Fraser, 1999). The three aforementioned aspects of animal welfare, which do relate and overlap (Von Keyserlingk et al., 2009), are valued differently by different groups in society (Fraser, 2008). In this paper, these aspects together are assumed to cover what determines animal welfare.

Assessing welfare impact of foot disorders. Ideally, welfare impact of foot disorders is assessed by determining how the cows' functioning, feeling and natural living are affected. Such effects are in the basis a result of the pain foot disorders cause (Flower and Weary, 2009). Pain, therefore, can be assumed to be a good indicator to assess welfare impact. The behavioral expressions of this pain are tender walking and lameness (Galindo and Broom, 2002) and locomotion scoring is the most common used instrument to assess the pain associated with foot disorders (Flower et al., 2008). Locomotion scores can be correlated with the severity of foot lesions (O' Callaghan et al., 2003; Whay et al., 1997; Winckler and Willen, 2001) and therefore will be used as a proxy of pain in this study. We used a scale and description of locomotion scoring on a scale from 1 to 5 (See Table 1), assuming that scores 1 and 2 indicated subclinical foot disorders (low degrees of pain; (severe) discomfort) and that scores of 3 and higher indicated clinical lameness. Subclinical cases are readily overlooked at first sight, but become visible by close inspection, for example, during foot trimming, or more critical assessment of locomotion.

Different foot disorders. A total of seven different foot disorders were distinguished, based on Somers et al. (2003) as described in the study by Bruijnis et al. (2010): the primary foot disorders interdigital phlegmon (IP), interdigital dermatitis and heel horn erosion (IDHE), digital dermatitis (DD), and sole hemorrhage (SoH), and the secondary foot disorders (subsequent to or as a consequence of another foot disorder) white line disease (WLD), sole ulcer (SUL), and interdigital hyperplasia (HYP). Briefly, IP is an acute, painful inflammation (Blowey and Weaver, 2003). Interdigital dermatitis and heel horn erosion (IDHE) were taken together as in other studies (Somers et al., 2003). IDHE is an epidermitis of the interdigital skin extending to the dermis, in many cases the infection extends to the heel horn. DD, often called Mortellaro's disease, is an infection of the epidermis of the hoof skin (Blowey and Weaver, 2003). SoH is damage to the corium as a result of metabolic disturbances and physical damage due to overloading and pressure on the claw. In the literature, the terms sole hemorrhage, subclinical laminitis and laminitis are used interchangeably. These are all diagnosed as hemorrhages in the sole and are, therefore, in this study all classified as SoH. Hemorrhages and lesions in the white line, mainly caused by physical damage, are categorized as WLD. SUL occurs after foot disorders like SoH and IDHE or after trauma and applies to all ulcers in the sole, toe and heel. HYP, commonly referred to as fibroma or tyloma, originates as a reaction to long-lasting inflammation of the interdigital cleft or IDHE. The disorder is recognizable by proliferation of the interdigital skin.

Table 1. Description of the five categories used to assess the pain impact of the different foot disorders, estimated locomotion scores using knowledge about pathophysiology, with a description of related pain intensity in parentheses

Locomotion score	Descriptive definition
1	Presence of a slightly asymmetric gait (discomfort)
2	Presence of an asymmetric gait (severe discomfort)
3	The cow clearly favored one or more limbs, moderately lame (pain)
4	Severely lame (severe pain)
5	Extremely lame, non-weight bearing lame (very severe pain)

Scores 1 and 2 represent subclinical foot disorders, scores 3, 4 and 5 represent clinical foot disorders, which cause lameness.

Modeling welfare impact

The model in our study is a stochastic dynamic simulation model, simulating at cow level. In our simulations, we assumed a farm with cubicle housing, with a concrete (slatted) floor, pasturing during summer period and two foot trimming interventions per year (spring and autumn). These characteristics represent a common dairy farm in The Netherlands. Input data for the assessment of welfare impact of foot disorders were based on literature and data obtained from experts in the field of dairy cow foot health.

In the following paragraphs a description is given of the different steps to model welfare impact of foot disorders. First, the modeling of foot disorders (foot disorder dynamics) is described, delivering the duration and incidence of the different foot disorders. Second, it is described how the pain impact is assessed. Third, an explanation is given about calculation of the welfare impact of different foot disorders Finally, the issue of weighing different parameters, pain and duration, to assess welfare impact is addressed.

Dynamics of foot disorders. The model on cow characteristics and foot disorder dynamics has been described in detail by Bruijnis et al. (2010). The model generates outcomes on the duration and the incidence of the different foot disorders, specified for subclinical and clinical stages. Data by Somers et al. (2003) and Frankena et al. (2009), a large field study on the occurrence of foot disorders on Dutch dairy farms (corresponding to our default farm), provided part of the underlying information and was complemented on foot disorders (a.o. Lischer et al., 2001; Holzhauer, 2006; Nielsen et al., 2009). Each run of the simulation model represents a cow. The foot disorders are simulated in time-steps of 1 month, for two consecutive years. The data of the second year are used for the welfare simulation, because at this point a steady-state situation has been achieved. For IP, a correction is made to account for the fact that this foot disorder normally is cured within a week (after treatment with antibiotics). For each time step (month) of the year, a cow can have three different statuses for the foot health: having no foot disorder, a subclinical foot disorder or a clinical foot disorder. The probabilities for a cow being in a certain state depend on the foot health status in the previous month and on cow characteristics like parity (first, second, third or fourth and higher calving cow), milk production level (high, average or low producing cow) and stage of lactation (number of months the cow is in lactation or dried-off). Using discrete functions the foot health status is determined for each month. A healthy cow has a probability of getting a foot disorder in the next month or stay healthy. All foot disorders, except IP and SUL, occur subclinically in the first month of presence. When a subclinical foot disorder is present, there is a probability the foot disorder cures (in case of a foot trimming intervention), the foot disorder stays present subclinically, or the foot disorder has a probability to become clinical in the next month. When a clinical foot disorder is present, there is a probability the foot disorder cures, depending on the probability of treatment and cure after treatment. Furthermore, the model includes the probability that a cow with a clinical foot disorder is culled, based on data about culling lame cows (Whitaker et al., 2004). Subsequently the outcomes on duration and incidence are used to assess welfare impact, using pain as indicator (see the section 'Assessing pain impact').

Assessing pain impact. The impact of foot disorders on welfare is assumed to be reflected by the associated pain. For this reason severity of pain, together with foot disorder duration and incidence, was used as parameter in the assessment of welfare impact. The pain caused by foot disorders, subclinical and clinical, was assessed by using information and knowledge on the pathophysiology of the foot disorders to estimate the associated locomotion scores, which is assumed to reflect pain impact of the foot disorder. The scoring scale as used for our assessment of pain was based on the different available scoring scales in literature where normally the scores of 3 and higher are assumed to be clinically lame cows (e.g., Bicalho et al., 2007; Garbarino et al., 2004; Manson and Leaver, 1988). The scores were based on findings from a literature study and a questionnaire among experts. Literature describing the type and characteristics of the foot disorders and the effects on locomotion was used to make this assessment. In order to substantiate the assessed pain impact of the different foot disorders using the literature, experts in the field of dairy cow foot health (mainly veterinarians) were consulted. Via a short questionnaire these experts were asked to assess the pain impact of each foot disorder, according to the scale as described in Table 1. The experts were asked to make their assessment on the basis of a typical case of a foot disorder on a common Dutch farm, as described earlier. The average of the assessments made by the experts was averaged with the authors' assessment based on literature. The resulting values for pain impact were used in calculation of welfare impact.

Calculation of welfare impact. The welfare impact (WI_i) of foot disorders for each individual cow, i, is calculated by multiplying the simulated incidence (i_{ij}) and duration (d_{ij}) of each of the five subclinical foot disorders (j; IDHE, DD, SoH, WLD and HYP) with the estimated pain for these subclinical foot disorders (p_j) and by multiplying the simulated incidence (i_{ik}) and duration (d_{ik}) of each of the seven clinical foot disorders (k; IP, IDHE, DD, SoH, WLD, SUL and HYP) with the estimated pain for these clinical foot disorders (p_k):

$$WI_i = \sum_{j=1}^{5} p_j \, x \, d_{ij} \, x \, i_{ij} + \sum_{k=1}^{7} p_k \, x \, d_{ik} \, x \, i_{ik}$$

These welfare impacts were used to calculate an average to represent herd level welfare impact of the foot disorders. The median and 25% and 75% percentile were calculated as well. The welfare impact of one case of a foot disorder, representing welfare impact on cow level, was calculated by correcting for the incidence of the foot disorder.

Weighing pain and duration. Default settings of model parameters include a scale of 1.0 through 5.0 for pain, foot disorder durations in months (maximum of 12) and incidence as number of cases per year. In this default situation no extra weight was given to any of the parameters or levels within the parameters, assuming a linear relation. The weighing of the parameters pain and duration, that is the ranking of the foot disorders, was benchmarked against information from literature. Literature was searched for information about the effects of specific foot disorders and degrees of pain (represented mostly by locomotion score) on the functioning and behavior of dairy cows. Relatively large differences between two adjacent pain levels in effects on animal functioning and behavior indicate a non-linear relation between pain levels and welfare impact.

Results

Dynamics of foot disorders

The simulation model produced the incidence and duration of the different foot disorders as presented in Table 2. Subclinical foot disorders have higher incidences and longer durations than clinical foot disorders.

Pain impact

Of 12 experts who were invited, 9 assessed the pain impact of specific foot disorders according to the scoring scale as presented in Table 1. Clinical foot disorders were estimated to have higher pain impact than subclinical foot disorders. IP has the highest score, an average score of 4.9, followed by SUL, with an average score of 3.9 (Table 3). These two foot disorders only occur as clinical foot disorder and have a relative short duration. The estimations of pain based on literature match with the assessments of the experts (being within the range of the experts' estimations).

Welfare impact

The welfare impact was calculated by using the assessed pain impact of the foot disorders, and duration and incidence as simulated by the model. The results indicate that on average a cow has a negative welfare impact of 12 (skewness = 1.5; 25% and 75% percentiles of 3 and 18 respectively, median = 9). The maximum score for welfare impact is 60, representing a cow with very severe pain during the whole year; thus, on average, a cow is estimated to experience 20% of the maximum welfare impact, which translates to, for example, having severe pain for 3 months. DD has a relatively high clinical occurrence (Table 2) and has the highest impact on dairy cow welfare, followed by SoH and IDHE (Table 4). SoH and IDHE have a high subclinical score (Table 3). The total welfare impact of subclinical foot disorders (54%) is comparable to the welfare impact of clinical foot disorders (46%). The welfare impact of IP, the foot disorder which is assessed to be the most painful foot disorder, is negligible (0.5%) particularly on herd level. At cow level, i.e. when excluding the effects of foot disorder incidences, clinical foot disorders have more impact than the subclinical ones (Table 5).

With the approach on cow level, the secondary foot disorders, HYP, SUL and WLD, have relatively higher impact than on herd level, mainly caused by its painfulness. Similar to the outcomes at herd level, the welfare impact of DD at cow level is high due to its painfulness, which is also the case for SUL and WLD. The results point out that subclinical foot disorders have a relatively high impact on welfare when taking into account the duration and incidence of a foot disorder, as subclinical foot disorders can be present for a long time (e.g., IDHE) or have a high incidence (SoH). The welfare consequences of subclinical foot disorders may be relatively minor compared to those of clinical foot disorder cases at individual cow level, but substantial at herd level.

Weighing pain and duration. The literature study reveals that consequences of foot disorders have been studied predominantly by using locomotion score. Most studies have not specified specific foot disorders or gradations in locomotion, typically the differentiation is made between lame and non-lame cows only, with locomotion score 3 and higher indicating lame cows. Some studies (e.g., Bicalho et al., 2007) did indicate relatively strong effects on cow functioning when locomotion scores became higher than 3, for example on reproduction. Such findings in literature suggest the use of a non-linear scale for the relation between severity of the disorder (pain) and duration when assessing welfare impact. However, there was insufficient information to back up a deviation from the default linear relationship. More research seems needed to relate effects to a specific foot disorder and different gradations of pain (other than lame or non-lame). In conclusion, literature did not provide the relevant information or reasons for adjusting the weighing of the parameters pain and duration.

Table 2. Incidence, cases/100 cows/year, and duration, in months, per case for the different foot disorders, by subclinical (SC) and clinical (C) cases in default situation (cubicle housing with concrete (slatted) floor, pasturing during summer (April through September), two foot trimming interventions per year (in April and October))

		IP	IDHE	DD	SoH	WLD	SUL	HYP
Incidence (i),								
cases/100 cows/yr	SC	-	38	27	54	9	-	5
	C	6	7	20	7	2	9	2
Duration (d),								
mo	SC	-	4.3	3.7	4.4	4.4	-	4.4
	C	0.2	3.5	3.5	3.5	2.9	2.6	4.1

IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia.

Table 3. Average pain impact based on locomotion score (scale 1 through 5) for the different foot disorders, subclinical (SC) and clinical (C) cases. The average of the assessments by the experts (n=9) and the assessments based on literature are used to calculate the average pain impact, the minimum and maximum estimation in parentheses

Pain (p)	IP	IDHE	DD	SoH	WLD	SUL	HYP
SC	-	1.1 (0;2.5)	1.3 (1;3.5)	1.0 (0;3)	0.9 (0;2.5)	-	1.6 (0;3)
C	4.9 (4;5)	3.3 (2.5-3.5)	3.4 (3;4)	3.1 (2;4)	3.5 (2.5;4)	3.9 (3;4.5)	2.9 (0;4)

IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia.

Table 4. Relative impact of the different foot disorders, subclinical (SC) and clinical (C), for the average welfare impact (representing herd level impact; pain x duration x incidence)

Welfare impact, %	IP	IDHE	DD	SoH	WLD	SUL	HYP
SC	-	14.8	11.5	21.0	3.3	-	3.2
C	0.5	7.2	20.7	6.3	2.1	7.9	1.6

IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia.

Table 5. Relative impact of the different foot disorders, subclinical (SC) and clinical (C), for the welfare impact per case of a foot disorder (representing cow level impact; pain x duration)

Welfare impact, %	IP	IDHE	DD	SoH	WLD	SUL	HYP
SC	-	4.9	5.3	4.8	4.5	-	7.9
C	1.1	12.3	12.8	11.6	10.8	11.0	12.8

IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia.

Discussion

This study applied a modeling approach to gain insight in the welfare impact of different foot disorders, both clinical and subclinical. Building this model and its outcomes support the identification of knowledge gaps, such as the lack of information on specific effects of foot disorders, in different types of severity and pain, on dairy cow behavior. The model addresses the weighing of different parameters involved in the welfare assessment, as related to foot disorders, and establishes transparency of the consequences of such weighing choices. This study reveals a considerable impact of foot disorders on dairy cow welfare. Insight in the magnitude of the problem of foot disorders and attention for the impact and importance with respect to animal welfare helps to raise the awareness of dairy farmers regarding the need to combat these foot disorders. Farmers value the importance of animal welfare differently and, depending on the farmer, demonstrable impact of foot disorders on animal welfare can be used as a motivator. Besides the importance of animal welfare, the interpretation of the concept of animal welfare can influence the farmer's priority for management improvements. Based on the results in our study the concept of animal welfare held by a farmer, for example mainly based on functioning or feeling, will not affect the priority because the results are not specified to that detail. More research is needed to obtain such knowledge. Insight in the effects on economic consequences plays an important role as well. A previous study showed that foot disorders cause substantial losses, which is likely to be underestimated as well (Bruijnis et al., 2010). The differential impact of specific foot disorders on dairy cow welfare and economics may help in setting priorities to approach the problem of foot disorders. Different intervention measures can be used to decrease the number and severity of foot disorders, for example rubber flooring to reduce pressure on the hoofs (e.g., SoH) and increase cow comfort or improve hygiene of the floor (e.g., IDHE) by more frequent or automatic scraping of the floor. Each measure affects a specific type of foot disorders and will influence the prioritization.

Results show specific impact of foot disorders on dairy cow welfare, mirroring differences in foot disorder painfulness, duration and incidence. On average, DD has highest impact on dairy cow welfare, because of a high incidence and clinical occurrence, and long duration. The varying impact of foot disorders is illustrated by the difference between IP and IDHE. During 1 year, on average only 6% of the cows get IP which causes very severe pain (category 5) for about one week. In contrast, more than half of the cows gets subclinical SoH for 4 months a year, having slight pain (category 1). The subclinical foot disorders SoH and IDHE, which are assumed to cause relatively little pain, are predicted to have a considerable impact on welfare due to a long duration and high incidence; the average welfare impact, representing herd level impact, of subclinical foot disorders is 54% of the total welfare impact due to foot disorders. Likely, farmers are unaware of these subclinical foot disorders, which (partly) explains why dairy farmers underestimate the occurrence of foot disorders, as found by Whay et al. (2002), and the associated impact on dairy cow welfare. The impact of subclinical foot disorders might be underestimated even more, because often these foot disorders occur bilaterally. In such cases a cow is less able to alleviate the pain by sparing the affected leg because both sides are painful. Detection is more difficult because the cows then ‘paddle’ with their hind legs, which is likely to worsen the underestimation by farmers. Simulation of the individual cow welfare, looking at one case of a foot disorder, pointed out the serious impact of the painful foot disorders, for example SUL. Such differences in welfare impact on herd level and individual level are also mentioned by Fitzpatrick et al. (2006): “… a low intensity pain but for a long duration, may be of different significance to an individual animal within a flock than a high intensity pain for a short duration, although in terms of flock welfare, both may have equal impact.” Considering the impact of foot disorders on welfare at the level of individuals or herds may both have its merits. Relatively much can be gained, that is, in terms of welfare, when preventive measures target subclinical and clinical foot disorders that have high impact on herd level. Curative measures could best target clinical foot disorders which have a high impact on individual cow level. A predominantly herd level approach is used already in existing health and welfare monitoring schemes (e.g., Welfare Quality®). The development in husbandry of increasing farm scale size, where attention for the individual cow becomes less likely, stimulates the use of welfare assessment protocols on herd level. Such approaches may underestimate the welfare reduction for individual cows suffering from a very painful foot disorder.

The results in our study are based on assumptions related to an average Dutch farm with cubicle housing with concrete (slatted) floor, pasturing during summer (April through September), two foot trimming interventions per year (in April and October). In practice, incidence and duration of the different foot disorders differ from farm to farm, because each farm has its own characteristics and specific management. The duration of the foot disorders, as simulated by our model, can be longer than reported elsewhere in literature, for example, Nielsen et al. (2009). This might be caused due to more accurate treatment in an experimental setting. Regarding the model outcomes on foot disorder incidence and prevalence, the results resemble the numbers reported in literature (Clarkson et al., 1996; Somers et al., 2003) supporting the validity of the model. For cows kept under conditions different from those assumed presently, the welfare impact of foot disorders will differ from present model predictions, for example, for cows kept on rubber floors, as the model assumes concrete flooring and rubber flooring improves locomotion (Rushen and De Passillé, 2006) and foot health (Vanegas et al., 2006). Also the accuracy of treatment of foot disorders by the farmer, which varies among farmers, affects the impact of the different foot disorders; more accurate treatment will reduce the severity and duration of foot disorders. The model is a flexible tool, it does allow a tailor made assessment, taking into account specific farm characteristics like rubber flooring. Also, future scientific findings can be used to upgrade the model and improve the assessment of welfare impact.

Our approach on animal welfare includes the three aspects as defined by Fraser et al. (1997). Foot disorder induced pain causes negative effects in all three domains, causing impaired health and functioning, suffering and affects the ability to perform natural behavior. Frasers' third domain of welfare, natural living, is of particular interest. Natural living is about more than being able to perform natural behavior, it is also about being able to have a normal life cycle. Foot disorders affect the longevity of cows, as the associated lameness and poor performance are an important reason to cull cows prematurely, as we have modeled. Including an impact value for premature culling in the assessment of welfare impact of foot disorders, therefore, would be valuable. This requires more specific information such as the average age of culling due to the specific foot disorders, which is not available at the moment. It will be challenging to weigh a decrease in life span against the presence of a foot disorder with certain severity and duration. Premature culling due to foot disorders occurs mainly when foot disorders are severe (clinical foot disorders) and are recurrent or long lasting. Lameness is one of the important reasons for culling a cow together with infertility and mastitis (Whitaker et al., 2004). Indirectly, there will be an added effect of lameness on culling as, like mastitis, it impacts negatively on fertility Garbarino et al., 2004; Ahmadzadeh et al., 2009). The impact of foot disorders on welfare because of these negative impacts on other health traits is likely to be underestimated in our model. Including longevity is likely to give more emphasis on the welfare impact of these severe foot disorders which cause premature culling, like SUL and recurrent cases of DD, and thus emphasize the importance of prevention and good treatment. Moreover, including longevity in welfare assessment helps to indicate whether farms 'solve' the health and welfare problem of foot disorders by culling cows instead of improving the circumstances and management to improve dairy cow foot health, and with that the welfare of the cows.

The choices for a herd or a cow level approach both bring weighing dilemmas. The herd level approach involves dealing with the trade-off between the importance of one severe case against multiple moderate cases. Using the cow level approach a comparable issue arises: how important is a long lasting case of a subclinical foot disorder, compared to a short lasting clinical foot disorder with high levels of pain. There is no objective method available to weigh foot disorder pain intensity, duration and incidence when assessing impact on welfare and as a starting point the present model assumes the most basic relationship; a linear one. During our quest to get more insight in the weighing of pain and duration in the assessment of welfare, we searched the literature to find specific information about the effects of foot disorders and lameness on the behavior of dairy cows. Using the existing literature we were not able to specify the relation between pain intensity and duration with animal welfare based on behavioral effects at certain pain levels and / or with certain duration. It is known that with very severe lameness, like with IP, the animals are not able to perform dairy cow-specific behaviors. However, it is not known at which pain intensity (represented by locomotion score as lameness is a behavioral expression of pain; Galindo and Broom, 2002) or combinations of pain intensity and duration behaviors are not performed anymore and what the (long-term) consequences are for the dairy cow. As there is not an objective method to assess welfare impact and literature did not provide enough information, the use of experts in the weighing of pain and duration could be useful to make an estimation. This has been addressed earlier by Roqueplo (1997): "Expert opinion can be used when no study has been run yet to address a specific point (but related studies can help form an opinion of what is most probable to be), and/or when scientific evidence alone cannot solve a problem." The experts that were consulted mainly were veterinarians in the field of dairy cattle. Veterinarians, qualified in dairy cattle, are knowledgeable on the various aspects of foot disorders, including locomotion, behavior and pathophysiology, but they expressed varying ideas about the weighing of pain and duration (data not shown). This selection of experts is likely to have steered results in one direction and the inclusion of other types of experts, e.g., ethologists or animal welfare specialist, is likely to further enlarge variation in such expert opinions. On average, the experts in our study valued pain intensity as more important than the duration of a foot disorder (data not shown). This outcome corresponds to human pain studies where duration had a smaller effect on pain experience by patients than pain intensity (Ariely, 1998). Severe pain leads to difficulties in performing normal behavior, affecting the health (aspect of functioning) and affective state (aspect of feeling) of the cow directly. In comparison to this, a cow suffering from a subclinical foot disorder experiences less pain and will be better able to perform the necessary behaviors to maintain good health e.g., going to the feeding fence and drinking bowl. However, over time relatively small changes in behavior, as resulted from moderate pain, can have considerable consequences. For example, cows with subclinical foot disorders may arrive later at and / or have unfavorable places at the feeding fence, resulting in lower feed intake, affecting the functioning of the cow, e.g., reduced milk production (Bach et al., 2007). Specific behaviors, like lying down and standing up, and expressing estrus behavior may be obstructed (Walker et al., 2008), leading to discomfort and frustration. Cows may adapt to the moderate pain they experience and the difficulties that it brings, as humans adapt to low levels of pain (Ariely, 1998). In the long term, however, adaptation capacities will be exceeded, as the enduring obstruction of normal behavior affects the functioning and health of the cow, leading to clinical foot disorders, subfertility (Melendez et al., 2003) and premature culling (Whitaker et al., 2004). It would be valuable to have more information on these issues. This requires laborious research into the different stages of the different foot disorders and the associated pain and effects on dairy cow functioning and behavior.

In practice, dairy farmers deal differently with foot health issues in their herd, possibly in part reflecting different ideas about animal welfare. Dairy farmers differ in how they value animal welfare and how they weigh between animal welfare and economics when implementing curative and / or preventive measures on the farm. Cost-effectiveness of measures and its effect on welfare may differ, for instance, investing in a rubber floor or improved lying surfaces for the cows could have substantial benefits for animal welfare but requires a large immediate investment compared with say improvement of foot trimming management or more thorough checks for foot disorders. Unfortunately, little is known regarding the precise effects of such interventions on dairy cow welfare and economics. Next to the differences in effect on economics and animal welfare, the type of investment and effect on daily routine will influence the decisions to take certain measures or not. The model provides insight in the complexity of the welfare impact of foot disorders. Our study stresses the need to increase awareness amongst farmers to prevent and remedy impaired foot health, taking into account the complexity of the different foot disorders, subclinical and clinical, at cow and at herd level. More insight in the consequences of foot disorders is also important to inform the public. Public awareness can stimulate the demand for improved foot health, as a measure to improve animal welfare and as such public perception can be an important actor in stimulating farmers to take action. To improve welfare assessment of foot disorders, scientific findings are needed to optimize the weighing of the painfulness, duration and incidence of foot disorders.

Conclusions

The impact of specific foot disorders on welfare was assessed by modeling the occurrence of foot disorders and the pain associated with it. On average, DD has highest impact on welfare, followed by SoH and IDHE. High clinical incidence of DD and high subclinical incidence of SoH and IDHE cause these results. On average, nearly half of the welfare impact (46%) is caused by clinical foot disorders. The fact that clinical and subclinical foot disorders contribute more or less equally to the effect on welfare, indicates that farmers may readily underestimate the related welfare impact by a factor two or more. Assessing welfare at individual cow level stresses the importance of pain intensity; the welfare impact of clinical and secondary foot disorders becomes more important. Different approaches on animal welfare assessment, like on herd or on cow level, give different results and may lead to different advices to the farmer. Better understanding of the impact of foot disorders on dairy cow welfare, as demonstrated by our model, should stimulate discussion about objective welfare assessment and, hopefully, stimulates improvement of future scientific studies. The objective and transparent assessment of the welfare impact of foot disorders determines knowledge gaps and helps to increase awareness about this problem and can support in determining strategies to establish good dairy cow foot health, for example by pointing out the considerable welfare impact of subclinical foot disorders.

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Chapter 4

Measures to improve dairy cow foot health: consequences for farmer income and dairy cow welfare

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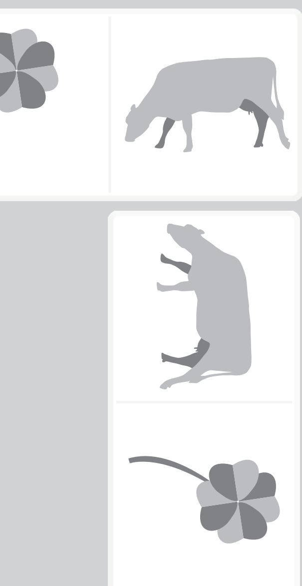

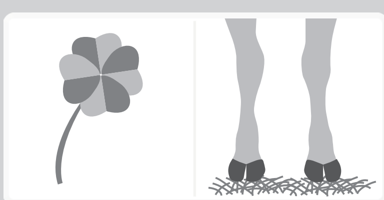

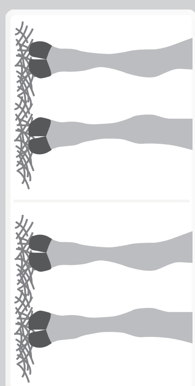

Abstract

Dairy farming in western countries with cubicle housing is an efficient way of dairy farming. Though, a disadvantage is the high prevalence and incidence of foot disorders (clinical and subclinical), which cause high economic losses and also seriously impair the welfare of dairy cattle. To point out the importance of reducing the amount and severity of foot disorders, advice to farmers should include information about the scale of the problem and the consequences in terms of economics and animal welfare. To provide support in making decisions on implementing intervention measures, insight into costs and benefits, of different measures should be available. The objective of this study, therefore, is to provide more insight into the costs and benefits, for farmer and cow, of different intervention measures to improve dairy cow foot health. Intervention measures were modeled when they were applicable on a dairy farm with cubicle housing and when sufficient information was available in literature. Net costs were calculated as the difference between the costs of the measure and the economic benefits resulting from the measure. Welfare benefits were calculated as well. Cost-effective measures are: improving lying surface (mattress and bedding, €7 and €1 per cow per year respectively), reducing stocking density (break even) and performing additional foot trimming (€1 per cow per year). Simultaneously, these measures have a relative high welfare benefit. Labor costs play an important role in the cost-effectiveness of labor-intensive measures. More insight into cost-effectiveness and welfare benefits of intervention measures can help to prioritize when choosing between intervention measures.

Key words: dairy cow welfare, foot disorder, modeling, intervention measure, costs

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Introduction

Dairy farming in western countries in its current form with cubicle housing and mainly concrete flooring is an efficient way of dairy farming in terms of labor and space requirements. A disadvantage is the high prevalence and incidence of foot disorders (clinical and subclinical; Hedges et al., 2001; Somers et al., 2003), which cause high economic losses (Bruijnis et al., 2010; Ettema et al., 2010) and also seriously impair the welfare of dairy cattle (Bruijnis et al., 2012). The different foot disorders are present in varying severities and have multifactorial risk factors making it a difficult health problem to combat (Ward, 2009). Another difficulty is the commitment of dairy farmers. Research has shown that farmers underestimate the scale of the problem and the effects on animal welfare (Leach et al., 2010). In order to improve dairy cow foot health, clear and unambiguous advice has to be given to the farmer. To point out the importance of reducing the presence and severity of foot disorders, advice should include information about the scale of the problem and the consequences in terms of economics and animal welfare. Different intervention measures can be taken to improve dairy cow foot health, such as improvement of the flooring (Vanegas et al., 2006), lying surface (Cook and Nordlund, 2009) and hygiene (Somers et al., 2005b), but also regular checking and trimming (Pavlenko et al., 2011). Each measure has its own effect on foot disorders. Different measures also require a different investment in terms of money and labor of the farmer. To provide support in making decisions on implementing intervention measures on dairy farms with cubicle housing, insight into costs and benefits of different measures should be available. Besides financial benefits of the measures, other benefits should be included as well because farmers are not only motivated by money, but also by a good health and welfare of the animals (Valeeva et al., 2007). The objective of this study, therefore, is to provide more insight into the costs and benefits for farmer and cow, of different intervention measures to improve dairy cow foot health in a cubicle housing system.

Materials and methods

To estimate the costs and benefits of different intervention measures, different steps have been taken in this research. The first step was a literature study to select the measures to be studied, including an estimation of the effect of these measures on the presence of the different foot disorders. The second step included the modeling of foot disorder dynamics and the effects of intervention measures on them, using a dynamic Monte Carlo simulation model. This was followed by a calculation of the benefits following from these effects. The costs of investing in intervention measures were calculated, to finally calculate the net costs of the intervention measures. A sensitivity analysis was performed to study the importance of the different parameters.

Selection of intervention measures

The literature study was aimed at seven important foot disorders as identified in our previous work (e.g., Bruijnis et al., 2010): interdigital phlegmon (IP), interdigital dermatitis and heel horn erosion (IDHE), digital dermatitis (DD), sole hemmorhages (SoH), white line disease (WLD), sole ulcer (SUL) and interdigital hyperplasia (HYP). Literature was searched for papers about lameness, foot-, claw- , or hoof disorders in dairy cattle and intervention measures. Papers were judged on relevancy based on type of study, research design (number of farms, animals), type of data (possibility to calculate efficacy of measures), country, experimental circumstances (e.g., housing, breed, climate*)*. The different intervention measures found in the literature were listed and subsequently the measures were evaluated on their applicability on a dairy farm with cubicle housing. Only those intervention measures applicable without a large renovation of the farm were included. The default dairy farm was a common Dutch dairy farm with cubicle housing, a concrete (slatted) floor, mainly Holstein Friesian dairy cows, pasturing during summer and two foot trimming interventions per year. Other common farm characteristics are an average milk production of 8500 kg, adjusted to production level, stage of lactation and parity, based on Dutch data (see Bruijnis et al., 2010). Further assumptions are: no overstocking (cubicle-cow ratio at least 1:1), standard dry cow management, milking and housing circumstances. The following measures were included: perform additional foot trimming, improve feeding management by improvement of structure and concentrate/roughage ratio and adding feed supplements, improve floor hygiene, improve the management of foot bathing (frequency, concentration, etc.), improve the lying surface (grip, softness, etc.), apply rubber flooring in the alleys, and reduce stocking density (Table 1).

Table 1. Selected intervention measures based on the applicability of the measure in a dairy farm with cubicle housing

Intervention measure	Description
Additional foot trimming	Improve foot trimming management, by including an extra foot trimming intervention at drying off
Feeding	Improve feeding: - improvement of the roughage and concentrate ratio, palatability and dry matter content; - use of supplement in feeding, minerals including biotin
Floor hygiene	Improve hygiene by clean and dry flooring
Foot bath	Improve foot bath management by more accurate application and increased frequency
Lying surface	Improve lying surface in cubicle by using more bedding material or better mattress
Rubber flooring	Apply a rubber floor in the alleys
Stocking density	Reduce stocking density to 95%

Estimating effects of intervention measures

The simulation model as used (see next paragraph) uses probabilities to simulate the chance that a cow gets a foot disorder. The chances depend on season and cow characteristics like parity and production level. The effect of intervention measures was modeled using an adjustment factor, representing the reduced probability to get a foot disorder by application of that measure. The adjustment factors were estimated using the available information from the literature and authors' expertise (Table 2). In case the literature did not provide quantitative information, qualitative information was used to estimate the direction and magnitude of the effect of a measure. If only the effects on one or a few of the distinguished foot disorders could be specified based on the literature, the effects were extrapolated to other foot disorders, using the available knowledge on the foot disorders and their etiology. The reasoning for this included the knowledge that the infectious foot disorders IDHE and DD were assumed to be influenced comparably by the intervention strategies because these foot disorders have some causative bacteria in common. For example Somers et al. (2005a, b), found that risk factors had an effect on these foot disorders in a comparable way. IP is an infectious foot disorder as well, though, information on the effect of interventions on IP is very scarce. The best described risk factors are cow-related factors such as stage of lactation (Alban et al., 1995). The logic about this foot disorder is mainly based on the fact that age and stage of lactation are important cow factors and that improvement in health status of other foot disorders is associated with improvement in IP (Alban et al., 1995). Furthermore, information about risks of infection about DD and IDHE have been extrapolated to IP in case the measure was likely to have an effect on the etiology of IP. SoH and WLD both are claw horn lesions (CHL) resulting from mechanical or physical damage and are also influenced by feeding ration (Webster, 2001). The effect of interventions on these foot disorders was assumed to be equal. SUL is a secondary foot disorder and associations between this foot disorder and SoH and IDHE have been found (Manske et al., 2002a; Van Amstel and Shearer, 2006a; author expertise). In case intervention measures affected these foot disorders, it has been assumed that SUL decreased similarly. HYP is also a secondary foot disorder and mainly follows after severe infections (Van Amstel and Shearer, 2006b; Watson, 2007). Therefore, it has been assumed that interventions reducing severe DD and IDHE also will reduce HYP. The adjustment factors for each intervention measure are given in Table 2 and are explained below.

Additional foot trimming. Application of extra foot trimming in a correct way and paying extra attention to foot health at certain periods of the lactation influences foot health positively (e.g., Manske et al., 2002b). Combined with the finding that foot trimming at drying off can result in a significant improvement (Hernandez et al., 2007; Garcia-Bracho et al., 2009), the factor for the improvement due to additional foot trimming was estimated.

Table 2. Estimated effects of the different intervention measures given as adjustment factor for the probability of getting a foot disorder compared with the default situation

Intervention measure	IP	IDHE	DD	SoH	WLD	SUL	HYP
Additional foot trimming	1.0	0.8	0.8	0.8	0.8	0.8	0.8
Feeding							
- management	1.0	0.9	0.9	0.8	0.8	0.9	0.9
- supplement	1.0	1.0	1.0	0.8	0.8	0.8	1.0
Floor hygiene	0.7	0.7	0.7	0.8	0.8	0.8	0.7
Foot bath	0.9	0.9	0.9	1.0	1.0	1.0	0.9
Lying surface	0.6	0.6	0.6	0.5	0.5	0.5	0.6
Rubber flooring	0.9	0.8	0.8	0.6	0.6	0.6	0.9
Stocking density	0.7	0.7	0.7	0.5	0.5	0.5	0.7

IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia.

The estimations are derived from available literature and existing knowledge, gray cells indicate that the estimation is based directly on numbers found in literature as well.

Feeding. A better feeding management by improving the ratio between concentrates and roughage and feed with more gradual transitions can improve claw health (Manson and Leaver, 1988; Somers et al., 2003). Studies on the effects of feed on lameness vary a lot, but it can be concluded that feeding primarily affects CHL (e.g., Leach et al., 2005). A more gradual step-up in concentrates had a positive effect on IDHE and DD (Somers et al., 2005a, b) and a high concentrate diet has been found to have a negative effect on DD (Olmos et al., 2009) and locomotion score (Onyiro et al., 2008). Sufficient levels of minerals in the feed are known to be essential in improving hoof quality. Studies on biotin did find no effects on IDHE but did find effects on SoH and WLD (Hedges et al., 2001; Bergsten et al., 2003).

Floor hygiene. Studies give varying results on the use of manure scrapers, possible due to varying circumstances in stocking density and speed and frequency of the scraper. However different studies have shown positive effects of hygienic, dry flooring on the occurrence of foot disorders (Somers et al., 2005a, b) which can be achieved by the use of a scraper or manure robot[1].

[1] Because we want to focus on measures that are executable without large renovation and in order to reduce the amount of measures the difference between a slatted and solid floor is not included.

Foot bath. Most studies aimed at agents which are allowed in The Netherlands do not find significant effects of foot bath management (Holzhauer et al., 2008; Thomsen et al., 2008). The effect on the foot disorders for which this measure is executed most, i.e. DD and IDHE, is therefore estimated to be small.

Lying surface. In general the possibility to lay down, lie and stand up comfortably are associated with a reduction in lame cows (Cook and Nordlund, 2009). Different studies provided numbers on reduction of foot disorders by improving design and bedding of cubicles (e.g., Philipot et al., 1994; Barker et al., 2009).

Rubber flooring. A reduction in the incidence or prevalence of foot disorders as a result of rubber flooring is found by Ouweltjes et al. (2009) and Vanegas et al. (2006). Combined with the findings that rubber increases comfort (Platz et al., 2008), it is reasoned that by providing more grip and reducing slips, injuries and damage to the feet (SoH, WLD and SUL) are prevented better than infectious foot disorders foot disorders (like DD) which are more associated to hygienic circumstances.

Stocking density. Direct effects of stocking density on foot health are not found in literature. It is known that overstocking leads to reduced lying and increased standing (Fregonesi et al., 2007) which is a risk factor for foot disorders (Leonard et al., 1996). As stocking density influences lying and standing time and social behavior, the effect is estimated to be in the range of flooring (walking, slips and resulting damages, etc.) and lying surface (lying time).

Modeling dynamics of foot disorders

The stochastic dynamic simulation model simulating economic consequences and welfare impact of different foot disorders, used in our previous studies (Bruijnis et al., 2010 and 2012), has been used for the current study. The default situation represents a common dairy farm in The Netherlands. The model simulates the presence of foot disorders per cow per year, depending on parity, stage of lactation, and milk production level. Each run of the simulation model represents a cow. The foot disorders are simulated in time-steps of one month. For IP, in the welfare calculation, a correction is made to account for the fact that this foot disorder normally is cured within a week (after treatment with antibiotics). In the model, there are three different states possible for foot health of a dairy cow: having no foot disorder, a subclinical foot disorder or a clinical foot disorder. A cow that has no foot disorder has a probability of getting one in the next month, depending on cow characteristics like the parity and milk production level. The modeled foot disorders, except

IP and SUL, first occur subclinically. When a subclinical foot disorder is present, the foot disorder has a probability to cure (in case of a foot trimming intervention), to remain the same, or to progress to a clinical foot disorder in the next month. A clinical foot disorder has a probability to cure, depending on the probability of treatment and the cure rate after treatment. Furthermore, the model includes the possibility that a cow with a clinical foot disorder is culled. The simulation model generates outcomes on the duration and the incidence of the different foot disorders, specified for subclinical and clinical stages, for each cow independently. Summing up the individual cow data gives the herd level results for presence of foot disorders. Subsequently these outcomes are used to calculate the economic consequences and welfare impact of the dairy cow foot health status on the farm. The modeling of cow characteristics, foot disorder dynamics and economic consequences has been described in detail by Bruijnis et al. (2010) and the modeling of welfare has been described in detail by Bruijnis et al. (2012). In short, the economic consequences distinguished are milk production losses (8% for clinical and 3% for subclinical foot disorders), prolonged calving interval (chance of 60% for clinical and 20% for subclinical foot disorders for an increase of 21 days), costs for labor of the farmer, foot trimmer and veterinarian, cost for treatment (e.g., antibiotics) and discarded milk. The welfare impact is estimated using the estimated pain of the clinical and subclinical occurrences of the foot disorders as a basis.

Calculating benefits of intervention measures

The probabilities for getting a foot disorder in the default situation were adjusted for the different intervention measures based on the estimated adjustment factors (Table 2), giving the economic losses and welfare impact of the foot disorders in the situations with the different intervention measures. Benefits of the intervention measures were calculated by taking the difference between the default situation and the situation where the intervention measure is applied, both for economics and welfare impact (where maximum welfare impact is 60).

Calculating costs of intervention measures

Costs of housing adjustments were calculated by using the prices of the investments, costs of installation, maintenance costs, depreciation and an interest rate of 5%. It was assumed that investments were made according to the operating instructions and implemented on a dairy farm with cubicle housing. Price information about investments and purchases was requested from at least at two different companies which supply the materials, using the current prices. Rubber flooring consists of covering the floor of the alleys with rubber. Improvement of lying surface consists of providing softer rubber mattress providing grip or providing more bedding. Floor hygiene measures relate to the investment of a manure scraper or manure robot to improve cleanliness of the flooring – assuming that no negative side effects can occur due to overstocking or due to speedy or too frequent use of the scraper – or increased manual cleaning of the alleys. Improving foot bath management is aimed at executing the measure in the most appropriate way. Because a specific advice for agent, frequency of treatment, etcetera is not available (Laven and Logue, 2006), the measure includes that the foot bath is applied in a suitable frequency, that the claws are cleaned before foot bathing, that a suitable disinfectant in the right concentration is used and that the number of cow passages per bath is limited and feet must dry before going into the barn again (Nuss, 2006). Costs for an improved foot bath management therefore include costs of a new foot bath, extra costs for the agent and labor due to extra treatments and pre-cleaning of the hooves. Additional foot trimming includes extra foot trimming at drying off, performed by a foot trimmer. There are two different measures relating to feeding. An improved feeding management includes costs for better roughage and concentrates. Feeding supplement includes costs for supplemental minerals. Costs for labor are calculated for the measures which need extra labor, like provide more bedding.

Net costs of intervention measures

The net costs of the intervention measures were calculated by calculating the difference between the calculated costs of the measures and the economic benefits, as estimated from the model simulations. This could be positive, meaning a cost, or negative, meaning a benefit (i.e. a cost-effective measure). Moreover, a net cost-welfare benefit ratio was calculated by dividing the net costs by the welfare benefit. The net cost-welfare benefit ratio gives the net costs per point of welfare improvement.

Sensitivity analysis

A sensitivity analysis was performed to obtain insight into the sensitivity of the estimated effects of the measures. For this purpose all adjustment factors (see Table 2) were increased and decreased with 0.1, giving insight into the effect of the efficacy of the measures.

Furthermore, the effect of different estimates of costs were made giving insight into the importance of different cost aspects of intervention measures.

Results

Costs and benefits of different intervention measures

The literature provided a very limited number of peer-reviewed articles providing quantitative data useful to estimate the efficacy of intervention measures. Adjustments of the probabilities for getting foot disorders were based on the current knowledge available (including personal communication and non peer-reviewed sources next to the peer-reviewed papers), resulting in the incidence as presented in Table 3. In the default situation the economic losses are €53 per cow per year and the average negative welfare impact per cow per year is 12 (where 60 is the maximum). The calculated costs for the different interventions vary between €7 per cow per year for additional foot trimming and €56 per cow per year for manual cleaning of the alleys. The benefits have a smaller range: economic benefits vary between €1 - €19 and animal welfare benefits between 0 and 4 per cow per year. Improving feeding and foot bath management have low values for economic and welfare benefits with relatively high net costs. Improving lying surface has the highest benefits and is a cost-effective measure (Table 4).

Table 3. Incidence of the different foot disorders, subclinical (SC) and clinical (C), by execution of the different intervention measures

		Incidence, cases/100 cows/year						
Intervention measure		IP	IDHE	DD	SoH	WLD	SUL	HYP
Default situation	SC	0	37	27	54	9	0	5
	C	6	7	20	7	3	9	1
Additional foot trimming	SC	0	31	22	45	7	0	4
	C	6	7	17	6	2	7	1
Feeding management	SC	0	34	25	45	8	0	4
	C	6	7	18	6	2	8	1
Feeding supplement	SC	0	37	27	45	7	0	5
	C	6	7	20	6	2	7	2
Floor hygiene	SC	0	28	20	45	7	0	4
	C	4	6	15	6	2	7	1
Foot bath	SC	0	34	25	53	9	0	4
	C	5	7	19	7	3	9	1
Lying surface	SC	0	24	17	30	5	0	3
	C	4	6	13	5	2	5	1
Rubber flooring	SC	0	31	22	36	6	0	4
	C	5	6	17	5	2	5	1
Stocking density	SC	0	28	20	30	5	0	3
	C	4	6	15	5	2	4	1

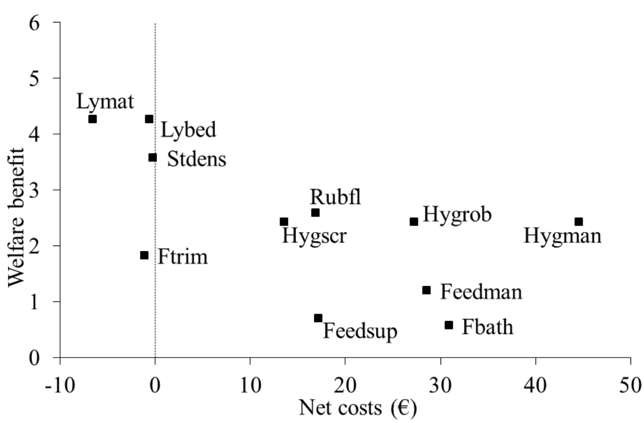
IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia.

The following intervention measures are cost-effective measures in terms of economics; lying surface (mattress and bedding, €7 and €1 per cow per year respectively.), stocking density (break even) and foot trimming (€1 per cow per year). Figure 1 shows the relation between welfare improvement and the net effect in economic terms. Costly measures, like manually cleaning the floor or foot bathing do not gain much in terms of welfare. Measures needing some investment and not being cost-effective can, however, result in substantial welfare benefit, like the application of a rubber floor or a manure scraper.

Table 4. Calculated costs and benefits for the different intervention measures

Intervention measure	Costs (€/cow/yr)	Benefits[1] (€/cow/yr)	Net costs (€/cow/yr)	Welfare[2] benefit
Additional foot trimming	7	8	-1	2
Feeding management	34	5	29	1
Feeding supplement	20	3	17	1
Floor hygiene, manure scraper	25	12	14	2
Floor hygiene, manure robot	39	12	27	2
Floor hygiene, manual	56	12	45	2
Foot bath	34	3	31	1
Lying surface, bedding	19	19	-1	4
Lying surface, mattress	13	19	-7	4
Rubber flooring	28	11	17	3
Stocking density	16	17	0	4

[1]In the default situation, foot disorders cause an economic loss of €53 per cow per year (Bruijnis et al., 2010).
[2]In the default situation, foot disorders cause on average a negative welfare impact of 12 per cow per year (Bruijnis et al., 2012).



Rubfl = Rubber flooring, Stdens = Stocking density, Lymat and Lybed = Lying surface, mattress or bedding respectively, Hygscr, Hygrob and Hygman = Floor hygiene by scraper, robot or manual cleaning respectively, Fbath = Foot bath, Ftrim = Foot trimming, Feedm = Feeding management, Feedsup = Feeding supplement

Figure 1. Effect of intervention measures on welfare benefits and net costs.

Sensitivity analysis

The results for the adjusted probabilities for getting a foot disorder, show that with the adjustment of 0.1 the cost-effectiveness of the measures does not change substantially (Table 5). The sensitivity of the costs for executing the measures shows that assumptions and specific circumstances can influence the results considerably. For example, excluding the costs for labor makes some measures much more interesting from cost-effectiveness point of view, as is the case for manual cleaning of the floor or foot bathing (Table 6). Moreover, the way a measure is executed can influence the cost-effectiveness considerably, e.g., when only putting rubber behind the feeding fence and waiting area, the measure almost becomes cost-effective. But also when less labor is needed to execute a measure, the measure becomes much more interesting, like foot bathing. A decrease in milk price will make it more attractive for farmers to reduce the number of cows, as positive effect on costs will increase considerable (>100% increase by decrease in milk price of 15%, Table 6).

Table 5. Sensitivity analysis; effects of intervention measures with higher or lower adjustment factors (plus or minus 0.1 respectively) for the probability of getting a foot disorder, showing the effects on net costs and welfare benefit

	Net costs (€/cow/yr)		Welfare benefit	
Intervention measure	Plus	Minus	Plus	Minus
Additional foot trimming	-5	3	3	1
Feeding management	25	33	2	0
Feeding supplement	12	18	2	0
Floor hygiene, manure scraper	9	18	3	1
Floor hygiene, manure robot	23	32	3	1
Floor hygiene, manual	40	49	3	1
Foot bath	26	34	1	0
Lying surface, bedding	-5	3	5	3
Lying surface, mattress	-11	-3	5	3
Rubber flooring	11	21	4	2
Stocking density	-5	4	5	3

Table 6. Sensitivity analysis; the effect of adjustments in the costs of intervention measures on the net cost-welfare benefit ratio

Measure specific cost adjustments	Welfare benefit	Net costs (€/cow/yr)	Ratio
Lying surface, bedding	4.3	-0.6	-0.1
- Decrease straw price / other package price (50%)		-9.9	-2.3
Lying surface, mattress	4.3	-6.5	-1.5
- Reduction purchase price (10%)		-7.4	-1.7
Stocking density	3.6	-0.2	-0.1
- Decrease milk price (15%)		-21.5	-6.0
Rubber flooring	2.6	16.9	6.5
- Rubber only behind feeding fence and waiting area		2.5	1.0
- Reduction purchase price (10%)		14.1	5.5
Floor hygiene, manual	2.4	44.6	18.4
- No labor costs		-11.6	-4.8
- Decrease daily labor (50%)		16.5	6.8
Floor hygiene, manure robot	2.4	27.3	11.2
- Reduction purchase price (10%)		24.4	10.0
Hygiene, manure scraper	2.4	13.6	5.6
- Reduction purchase price (10%)		11.8	4.9
Foot trimming	1.8	-1.1	-0.6
- No call out charges		-3.2	-1.7
Feeding management	1.2	28.5	23.8
- Decrease in percentage higher costs (40%)		15.1	12.6
Feeding supplement	0.7	17.2	24.5
- Reduction purchase price (33%)		10.4	14.8
Foot bath	0.6	30.9	54.2
- No labor costs		7.8	13.8
- Decrease labor time (33%)		23.2	40.7
- Decrease costs agent (33%)		27.7	48.6
- Decrease costs foot bath (33%)		30.6	53.7

Discussion

The presented results give insight into the costs and benefits of different intervention measures to improve dairy cow foot health. The study aimed at intervention measures, which are applicable on a dairy farm with cubicle housing. Measures were included when a reasonable estimation could be made, based on literature and expert knowledge, about the effects on dairy cow foot health. For different measures the amount of information was insufficient to model the effects, e.g., improved heifer management as mentioned by Rouha-Mülleder et al. (2009), where a good description of the measure and the expected effects are lacking. A very important intervention measure is management improvement by the farmer; ‘stockmanship’. Hanna et al. (2009) suggested that stockperson attitude may be important in relation to dairy cow welfare, and different studies show that knowledge and awareness and an active attitude result in fewer foot disorders and lameness (Barker et al., 2010; Mill and Ward, 1994). The efficacy depends on the degree of effort, knowledge and awareness of the farmer. Improvement can be achieved by a shorter duration or less severe cases because of quicker treatment or because of preventing new cases better. An informed estimate for these effects is hardly possible. The degree of knowledge and the willingness and effort to change are hard to estimate and very complicated to model. Assuming that the number of cases of foot disorders will decrease with 50%, results in a reduction of costs of €26 and will need an investment of €19 per cow per year (data not shown). This results in a benefit of €7 per cow per year, but requires labor effort and attitude change of the farmer. Although modeling stockmanship is very tricky, this example shows there is a lot to gain by improving the knowledge and efforts of the farmer. Other possible fruitful measures which we did not include in the model were adjusted breeding and putting dry cows in a straw yard. Both have potential to improve dairy cow foot health. Selection for better foot health using breeding values is possible, where selection only on legs is expected to have a positive effect on improving foot health (personal communication R. van der Linde (CRV); Olmos et al., 2009; CRV, 2010) or by cross breeding with other breeds. This type of intervention is a long term intervention and the effects on foot health and economics depend strongly on the choices made. This influenced for example the extent of reduced progress of other characteristics. These difficulties in estimating the effects make it hard to quantify the effects. Keeping dry cows in straw yards is also a good measure to reduce the incidence of foot disorders, where the effect on claw horn lesions (like SoH and WLD) is found to be much higher than for the infectious foot disorders (Rouha-Mülleder et al., 2009; Somers et al., 2005a). However the extent of effect and the way to execute the measure vary a lot and were therefore not modeled.

The literature study showed variable information about the effects of measures to improve dairy cow foot health. First, this is illustrated by the scarce amount of data which could be derived from literature. As is shown in Table 2, only for a few foot disorders quantitative information is available on the effects of intervention measures. Furthermore, different studies gave ambiguous information about the effects of the measures, for example foot trimming. Some studies show that foot trimming can be a fruitful measure in preventing foot disorders (Ando et al., 2008) while others show that foot trimming can be a risk factor (e.g., Amory et al., 2006). The latter can be explained by the fact that foot trimming can be applied when there are problems with foot health already. Farmers experience this diversity of reported effects in different, and sometimes contradicting, advices. This does not support the farmers in taking real action and to implement the measures properly.

From the selected measures only a few were cost-effective in the default calculation: improving lying surface with a mattress (€7 per cow per year) or bedding (€1 per cow per year), foot trimming (€1 per cow per year) or reducing stocking density (€0 per cow per year). Furthermore the range of costs to implement the measures was large: €7 per cow per year for additional foot trimming and €56 per cow per year for manual cleaning of the floor. The benefits contrasting these costs vary as well. Some rather costly measures, like improved feeding, have low benefits, making the measure less interesting compared to, for example, rubber flooring where the investment is compensated by relative high economic and welfare benefit. An argument which makes the measures of feed improvement more interesting is the fact that these measures are easy to implement without a big investment, labor effort or routine adjustment. Because such factors are important when choosing between possible intervention measures (Huijps et al., 2009), improving feed composition still can be an interesting measure for certain farmers.

The sensitivity analysis showed the variability of the effects as estimated in the default calculation. The adjustments of the probabilities to get a foot disorder can make a difference for being cost-effective or not, as is the case for stocking density or the use of bedding. The model used in this study is adjustable and can be used to model new findings, ideas or developments. For example, the effects of including a 'comfort-effect' of intervention measures can be evaluated. Some measures do not only increase welfare by preventing new foot disorders, but also by reducing impact severity (without necessarily reducing the occurrence of foot disorders), because of a higher comfort of the cows. Including this 'comfort-effect' the pain severity and the percentage of milk production losses can be adjusted to values which reflect the reduced impact of foot disorders. Improved cow comfort could, for example, be achieved by the use of rubber on the floor (Kremer et al., 2007; Platz et al., 2008). Including the comfort-effect for the measures having a comfort increasing effect, can change the ranking of the measures. For example rubber flooring, which is preferred by dairy cows (Telezhenko et al., 2007), costs only €1 for each point of welfare benefit when including a comfort-effect compared to €6.5 in the default situation and a comparable effect is visible for an increased floor hygiene. The use of other measures, like a straw yard for dry cows, becomes more interesting when including the effect of more comfort (data not shown). The measures still might not be cost-effective, though, it becomes more interesting to improve foot health because animal health and welfare are valued as important by farmers as well (Valeeva et al., 2005). Moreover, when the improvement of welfare is valued as relatively important compared to the net costs, it might change the preference for some of the measures considerably. Furthermore, this can be a trigger for the sector to invest in such measures or for a government to subsidize the implementation of a comfort measure, such as rubber flooring, especially when the demand from society for animal welfare friendly produced food grows.

Labor requirements and daily routine of the farmer do play a role as well for the preference of executing measures. A measure requiring a lot of labor of the dairy farmer is likely to be less preferred than a measure which does not need labor effort (Huijps et al., 2009). Labor costs are important for the cost-effectiveness of certain measures, like manual floor scraping or foot bathing. Development of technical applications, like a manure scraper or robot or an automatic foot bath may be a solution to overcome these labor costs (partly), especially because the type of labor is tedious. Foot bathing has another disadvantage next to the labor requirements: the action of putting the cows through the bath is stressful and sometimes even painful for the cow. Therefore a discomfort effect could be added for this measure when choosing between different measures.

This study focuses only on the modeling of one measure at a time while foot disorders have multifactorial causes. The effect of one measure can be disappointing when other factors still are unfavorable. It would be valuable to model the combined effect of measures because this can give a more accurate estimation of the effects of measures. Moreover, the modeling of interaction between foot disorders would add much value, however, to be able to do this more knowledge is needed. This study is limited to providing insight in the effects of measures applicable on a standard dairy farm with cubicles. Each farm, with specific housing circumstances and management decisions by the farmer will give varying results because of varying risk levels (Ettema et al., 2009), however, we have gained insight in the most likely effects of specific measures which can be executed in a cubicle housing system, represented by our default situation. A very important possibility to improve dairy cow foot health, and with that the welfare of dairy cows, is the use of other types of housing systems, like the use of a straw yard, or new types of free stalls like a compost barn where there are no cubicles but a light and spacious barn with compost as bedding. Transition from a cubicle housing to such a system needs a large renovation or asks for the building of a new barn and is therefore not included in this study. However, when a farmer is planning to rebuild or build a new barn, this option is worth considering. Though, there might be a disadvantage for the farmer (e.g., labor efficiency), by taking into account the positive effects (e.g., a reduced prevalence, reduced failure costs and improved cow comfort), this option might be very interesting.

Conclusion

Present study gives insight into the costs and benefits of different intervention measures to improve dairy cow foot health. The following intervention measures are cost-effective in our default calculation: improve lying surface (mattress and bedding, €7 and €1 per cow per year respectively), reduce stocking density (break even) and perform additional foot trimming (€1 per cow per year). These measures have a relative high welfare benefit as well. The priority setting can be different for specific circumstances (e.g., a different default situation with overstocking and / or no foot trimming at all). The prioritization can also change due to different assumptions about the measures or by different ways of executing a measure. The cost-effectiveness of labor intensive measures, for example, is affected by the amount of labor and the value given to labor.

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Chapter 5

Longevity as an animal welfare issue applied to the case of foot disorders in dairy cattle

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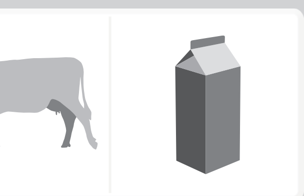

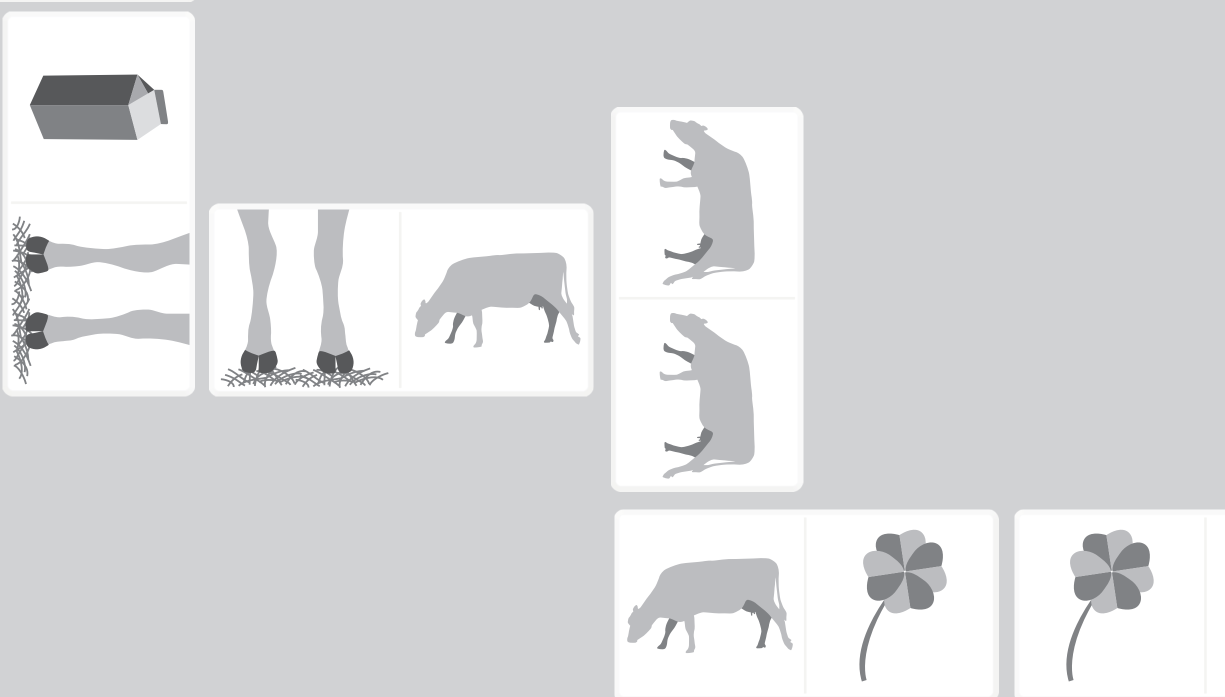

Abstract

In current dairy farming it is possible to run a profitable farm without having to adapt the system to the needs of dairy cows. In such systems the interests of the farmer and animals often diverge. Consequently, specific animal welfare problems occur. Foot disorders in dairy cattle are an illustrative example resulting from the specific methods of housing and management in current dairy farming. Foot disorders and the resulting lameness are considered the most important welfare problem in dairy farming. However, these foot disorders not only typify welfare problems related to certain housing systems, but they also lead to the premature culling of cows. The assessment of the impact of foot disorders on the welfare of dairy cows raised the question of whether premature culling affects animal welfare since it affects the longevity of a cow. We argue that this aspect of longevity is morally relevant as an animal welfare issue. In this paper we aim to explore whether longevity is both (a) a morally relevant aspect in the discussion on killing animals and (b) a constitutive element of animal welfare. In other words, we aim to explore whether longevity is an independent moral argument in an animal welfare discussion. We claim that longevity is not merely important as an indicator of animal welfare, but is also a constitutive element of animal welfare. We argue that we need a more integrated approach to animal welfare and that an assessment that includes the aspect of time is necessary. This view involves a shift from views on animal welfare in terms of functioning or feeling well to a view on animal welfare that includes the aspect of natural living in which species-specific development is important. To show the impact of these points of view, we look at the practical implications for choices concerning the management of foot disorders in dairy cattle.

Key words: animal welfare, longevity, dairy cow, foot disorders

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Introduction

Over the last few decades animal production, including dairy farming, has increased and specialized considerably, leading to intensification and scale enlargement. In The Netherlands, the average milk production in the past 10 years has increased from almost 7,500 liters per cow per year to approximately 8,000 liters nowadays (LEI). In the same period, the number of farms has decreased while the number of cows per farm has increased from an average of 60 to 75 dairy cows per farm (LEI). A labor and cost-effective housing system for such large herds of dairy cows is the cubicle housing system. Currently the main housing system in The Netherlands consists of cubicles where dairy cows can lie and rest and walking alleys, which mostly consist of concrete (slatted) floors. In these housing systems approximately 80% of the cows have one or more foot disorders, and about one third of these cows become lame in a year (Frankena et al., 2009; Somers et al., 2003). Due to the incidence, duration and severity of these foot disorders and the resulting lameness, these problems are considered the main welfare issue for dairy cattle kept in cubicle housing systems (Algers et al., 2009; Anonymous, 2001).

Foot disorders may cause long-lasting and intense pain. Consequently, the animal will experience difficulties in walking, lying down, and standing up (Cook and Nordlund, 2009), affecting the ability of dairy cows to perform their natural behavior and fulfill species-specific needs. Furthermore, foot disorders affect other aspects of the cow's functioning, e.g., a reduced milk production (Warnick et al., 2001) and a diminished reproductive performance. As a result, cows suffering from clinical foot disorders have a higher probability of being culled (Machado et al., 2010). Even though the majority of foot disorders occurs subclinically without causing lameness (Dyer et al., 2007), this "does not imply that an animal is not suffering" (Somers, 2004).

In order to prevent or treat foot disorders, farmers, foot trimmers, and veterinarians are regularly confronted with the question of how this problem should be addressed. Should the foot disorder be treated or should the cow be culled or euthanized? Culling means the removal of a cow from the farm, in general for slaughter. A visibly lame cow, however, needs to be euthanized on the farm because of animal welfare and food security reasons and will therefore be destroyed instead of slaughtered for meat. In addition to the influence of specific economic circumstances, the answer to these questions on how to treat foot disorders depends on one's view on animal welfare and touches upon the issue of longevity. Culling or euthanizing because of lameness implies the decision to end the life of an animal prematurely, i.e. before the end of a normally intended productive life, either because of direct welfare reasons or because the animal is not producing well and/or costs the farmer money and time (Booth et al., 2004).

In this paper the aspect of longevity implies the duration of life in terms of the intended lifespan of an animal. This topic has received considerable attention in the past few years. In the context of sustainable farming and improving farm management, dairy farmers aim to have robust and healthy cows that lactate easily and abundantly. Moreover, concern about the lifespan of dairy cattle has been put forward by the Farm Animal Welfare Council (FAWC, 2009), who stated that a 2-year increase in lifespan would be desirable and possible. This would create a lifespan of 8 years, which equals a productive life of 6 years. Such an intended lifespan should be possible because a dairy cow can reach the age of 20 or more. In this paper we focus on the role of longevity before the cow reaches the intended life span because in Dutch society most people accept slaughtering animals for food (Rutgers et al., 2003).

While assessing the welfare impact of this most important welfare problem in dairy farming, the question emerged as to what extent premature culling has an impact on dairy cow welfare. It is agreed that a short lifespan can indicate an affected welfare (Broom, 2007). In this paper we aim to go one step further and explore whether longevity is both (a) a morally relevant aspect in the discussion on killing animals and (b) a constitutive element of animal welfare. In other words, we aim to explore whether longevity is an independent moral argument in an animal welfare discussion.

We apply our analysis of longevity as a morally relevant welfare issue to the above-mentioned problems of foot disorders in dairy cattle. Our choice for this focus is not because foot disorders are the only problems in dairy cattle that lead to premature culling. Fertility problems would be important in this context too (e.g., Ahlman et al., 2011). However, foot disorders and lameness are highly important welfare problems in dairy farming that (a) are currently underestimated (e.g., Leach et al., 2010) and (b) lead to other health problems and dilemmas related to longevity.

Modern animal farming and related animal welfare issues

In general, it is currently possible to run a profitable farm that genuinely contributes to food security and food safety without having to adapt the housing system to the (behavioral) needs or interests of the individual animals. Consequently, the interests of farmer and animal diverge and give rise to animal welfare problems like behavioral and social restriction, overcrowding, and production-related diseases specific to the systems the animals are kept in (like foot disorders and lameness in dairy cattle). In situations in which the interests of farmer and animal diverge, problems of animal welfare do not merely result from cruelty or ignorance but they also start in the conflict between the interest in producing safe and cheap food in sufficient quantities and the interests of the animal (Rollin, 2004). Nonetheless, the problems of animal welfare in general and, more specifically, the issue of foot disorders cannot be seen as a conflict of interests only (cf. Ohl and Van der Staay, 2012). A clear moral dimension underlies the conflicts of interests themselves and the proposed answers to these conflicts. It is not only a matter of paying due respect to these interests, i.e., striving for what is most suitable for all involved parties, but it also touches upon fundamental moral questions of whether animals belong to our moral community and what we owe to animals. At this point, there is a plurality of views. The answers to the basic question of whether animals are part of our moral community are extremely diverse. Consequently, there are also many ideas on the content and relevance of animal welfare and on how to solve the current questions of animal welfare in animal production.

Thus the problem that started with a conflict of interests is rooted in a plurality of moral views on what we owe to animals. This plurality results in different views on animal welfare.

As the aim of this paper is to analyze whether longevity is a morally relevant issue within an animal welfare discussion, an analysis of longevity in relation to animal welfare is needed. In the next sections we discern six normative views that help to analyze longevity as a moral issue. First, we shortly discuss two views that link the moral importance of longevity to the value of life rather than to animal welfare. Second, we make a more detailed analysis of four views on longevity in relation to animal welfare. Finally, we draw conclusions on the relevance and implications of longevity as an animal welfare issue.

Longevity, the value of life and respect for individuality

A first view that considers longevity as a morally relevant aspect starts with the idea of respect for life. Respect for life, according to Taylor (1986), means that life as such is worthwhile protecting if a being has a 'good of its own'. From this perspective interfering in the lifespan of a living being that has a good of its own is morally problematic as it affects the good of the animal and runs counter to the duty to pay due respect to each being that has a good of its own. However, to come to this conclusion, this view on respect for life does not need to refer to animal welfare. Thus in this view longevity is a morally relevant aspect but not as an issue of animal welfare.

A second view starts with 'respect for individuality' in which those who are subject-of-a-life have inherent worth[1] and as such are worthwhile protecting (Regan, 1983). Therefore, interfering in the life span of a subject-of-a-life is a no-go area. Animal capacities like having a future orientation, awareness, or self-awareness are relevant if these capacities are a condition for a being to be defined as subject-of-a-life and therefore give much importance to longevity. However, just as with a Taylorian account, the line followed by Regan will grant longevity moral importance but not as an issue of animal welfare.

According to these views of 'respect for life' and 'respect for individuality' the question of longevity raised in the welfare assessment of the treatment of foot disorders is appropriate

[1] Regan speaks about inherent value, but this has a stronger claim than the classical use of the concept as introduced by Lewis (1946). Therefore, we speak of inherent worth.

because it is a morally relevant aspect in the discussion on killing animals; nevertheless, it is not genuinely linked to animal welfare. Moreover, the relevance of longevity is not considered to be specific to housing or management-related animal diseases (like foot disorders). The 'respect for life' and 'respect for individuality' views consider keeping animals for production aims highly problematic, if not fully unacceptable. An evaluation of this latter normative claim is beyond the scope of this paper. However, these views do not directly explain why longevity is also mentioned in animal welfare discussions by people who appear to have no fundamental problems with keeping animals for food production. Therefore, we now wish to look at normative views in which animal welfare plays a central role.

Longevity and animal welfare

In the practice of animal production, welfare issues arise since animal interests are at stake. As Yeates (2009) states: "… one condition for an issue being a welfare issue is that its assessment as an issue involves (or ought to involve) an evaluation of states with regard to an animal's interests." In line with what we have claimed about interests in the introductory section on the conflicts in the practice of animal production, speaking about the interests of animals is also not a value-free act. Starting animal welfare discussions from the viewpoint of animal interests perfectly shows the interrelation of the normatively and biologically based elements of animal welfare.

Both biological and normative assumptions define to what extent an animal has interests, what these interests are and what they imply for our dealings with animals. The combination of one's biological and normative value assumptions leads to specific views on animal welfare and – as we claim - also on whether longevity is an aspect that has added value in the welfare discussion. This can be illustrated by combining three views on animal welfare based on biological knowledge (e.g., biology, ethology, and physiology) with four views based on moral norms on animals and their welfare. For the biologically based views on animal welfare, we - following Fraser –distinguish three views: animal welfare as a matter of functioning well, feeling well, and leading natural lives (Fraser et al., 1997). We are aware that, in practice, these often overlap. However, in essence they have different biological starting points in which the different views do not rule out the previous view(s), e.g., when the view on feeling is adopted, the functioning view continues.

Moreover, these biological views can be related to the four normative views about animal welfare that we distinguish and that indicate the moral importance of animal welfare and our duties towards animals. The normative views assume that sentient beings should (a) be able to function well, (b) feel well, (c) be able to satisfy preferences, and (d) should be able to develop according to species-specific needs and capabilities.

If the three biological views on welfare are combined with the four normative views, we do not end up with a matrix of twelve possible views on animal welfare because consistency requires a certain balance in biological and normative views. It would, for instance, be problematic to stress the importance of species-specific behavior in biological terms but deny the moral importance of satisfying species-specific needs at the same time. Table 1 shows the relevant views and the role longevity plays in these views on animal welfare. In the next sections we elaborate on three roles longevity can play in the animal welfare debate. Starting as an indicator and evolving into an independent moral argument, the latter making it an animal welfare issue.

Longevity as indicator of animal welfare

A first view on animal welfare focuses on the functioning and health of the animal; here welfare implies that the animal is free from diseases and has the ability to function well, e.g., the ability to grow and to reproduce. Farmers in particular use this view on welfare when, for instance, they argue that if they take good care of the animals, the animals will produce well and therefore enjoy good welfare (De Greef et al., 2006). From this perspective a reference to longevity is not part of the concept of welfare but is an indicator of welfare. Longevity indicates that the animal's health and functioning is not compromised to such an extent that the life span is affected.

This idea of longevity as an indicator of welfare can also be recognized in those views that include the feelings of animals in the concept of welfare (Broom, 1986; Broom, 2007; Bracke and Hopster, 2006). By stressing the role feelings play in relation to welfare, some go further by arguing that, in addition to avoiding negative welfare, positive feelings are essential for animal welfare (Spruijt et al., 2001). This view often comes with the moral claim that animals – as sentient beings who can feel pain – should be granted moral status and are legitimate objects of moral concern.

Table 1. Relation between biological and normative views on animal welfare and the relation with longevity, starting as an indicator and evolving into an independent moral argument

Biological views on animal welfare		Normative views on animal welfare evaluation		Role that longevity plays
Functioning, health	→	Functioning well	→	Indicator
Feeling	→	Feeling well	↗ →	Precondition
	↘	Preference satisfaction	→	Moral argument
Natural living	→	Species-specific development	↗	

Nonetheless, the emphasis on feelings does not necessarily imply that longevity plays a role as an independent moral argument in welfare discussions. It is often considered that death and longevity as such are not an animal welfare issue (e.g., Broom, 1988; Webster, 1995). From this perspective, the moral intuition that killing includes a moral wrong is not denied, but it is argued that longevity is not a legitimate argument to substantiate this intuition. Those upholding this view argue that longevity is not relevant because animals have no or an insufficient concept of time. Consequently, they lack the awareness of their future and cannot weigh future benefits against current misery. Thus an animal does not comprehend extra life (cf. Lund and Olsson, 2006; Rollin, 2006). The argument usually includes the following steps: a cow on a dairy farm has to be culled anyway. If the animal is culled in a welfare-neutral way, then there is no harm in killing animals because for the cow it does not matter whether and at what age it will be culled. Thus longevity only plays a role as an indicator of (restricted) animal welfare. For instance, if an animal is culled prematurely because of health and welfare problems, restricted longevity is often seen as an indicator of reduced animal welfare (e.g., Broom, 2007).

In the case of foot disorders, longevity indicates animal welfare problems if many cows are culled due to such disorders. Culling healthy cows before the intended lifespan has been reached is not a welfare issue as such. For instance, when the farmer wants to replace dairy cows with genetically superior young stock, there are no welfare problems because killing is not seen as a welfare issue. If a cow has a foot disorder that is treatable and can result in recovery, a dairy farmer has to decide whether to treat or prematurely cull the cow. In general this assessment depends on how likely recovery will be, the probability that the foot disorder will return and to what extent the cow is affected in its functioning and feeling. Specific decisions need to be made for the different foot disorders of varying severity. As long as the killing itself is not seen as problematic for animal welfare and reduced longevity can only indicate affected welfare, then the decision depends on how the farm-technical aspects are weighed against the functioning and feeling of the cow. A decision to bring the cow to slaughter can be seen as a good solution because it will stop the negative impact on welfare.

This may result in a counterintuitive situation. Because killing the animal is not a welfare issue and it even might be the preferred option if the cows really suffer or if they do not function properly from the perspective of production, then a herd-level welfare assessment might give the impression that such a farm scores well on animal welfare. Relatively few animals have a health problem at the moment of assessment. However, in reality this so-called positive result is achieved because the problems affecting welfare are ‘solved’ by culling or euthanizing the animals rather than by improving animal welfare by better prevention and earlier treatment of foot disorders.

Longevity as a precondition for animal welfare

The view on welfare that considers the feelings of animals as the key element of animal welfare also includes the possibility of considering longevity as a precondition for animal welfare rather than an indicator only. Sapontzis already argued that life has important instrumental value, for living things that have interests (1987, 166-170). Without continuing to live, the animal cannot fulfill its interests. From this perspective, a premature death not only implies depriving an animal of its life, but it also "deprives it of a future in which it could pursue its interests" (Haynes, 2008, p. 54). Balcombe (2009) starts from a hedonistic utilitarianism and argues: “Pleasure has moral import for practises like factory farming and laboratory research, for it amplifies the moral burden of depriving animals the opportunity to lead fulfilling enjoying lives.” From a similar normative perspective, Bradley (2009) states: “There is no good reason to discount the badness of death for an animal. If an animal would have had a good life, then killing it is bad for it, even if it cannot contemplate its future.”

From this view, being alive is a precondition. It is a condition sine qua non to be able to feel and to experience positive feelings as something intrinsically good. Depriving an animal of a positive future harms it because positive welfare is taken away (Balcombe, 2009). Consequently, this view considers lifespan as a relevant notion in the moral assessment of a practice of animal use because the duration of life directly influences the ability to have positive experiences.[2]

It is now possible to explore the implications of the views on welfare that are based on the animals’ feelings in the case of foot disorders. In comparison to health and functioning, feelings play an especially important role in deciding whether the cow has a life worth living (feeling well). Compared to the functioning views, the affected welfare during the presence of a foot disorder needs to be considered in addition to the production level and health parameters. The use of analgesics for lame cows is not a common practice in dairy farming (O' Callaghan, 2002). Improving welfare by better pain medication and increased cow comfort, like improving lying and walking surfaces for at least the lame cows, should be given more attention and put into practice according to the views on feeling. The extent to which the dairy farmer will implement these measures to promote animal welfare depends on the practical and economic possibilities as well as the farmer’s assessment of the negative welfare impact of the various foot disorders. The decision to cull a cow could also be for the sake of the cow because cows might suffer too long. This shows that longevity is more than a mere indicator of welfare but it is still not morally relevant for its own sake. Longevity is a welfare issue that needs to contribute to the quality of the life of the animal.

[2] A cynical counterargument in relation to (dairy) farming could be that it is questionable in the first place whether dairy cows have a good life at all. In this paper we assume that keeping dairy cows does not exclude the premise that cows can have a life worth living.

Because the aim of this paper is to explore whether longevity is both (a) a morally relevant concept in the discussion on killing animals and (b) a constitutive element of animal welfare, the idea of longevity as a precondition does not appear to meet both conditions. From Sapontzis's viewpoint and from the viewpoint of hedonistic utilitarianism, lifespan is not morally irrelevant but it does not serve as a constitutive element in the moral assessment of animal use or animal welfare. Since only fulfillment of interests or pleasure are considered to be intrinsically good, longevity does not play an independent role.

Longevity as an independent moral argument in the animal welfare discussion

Preference satisfaction. Animal welfare defined in terms of animal feelings can be combined with the normative view on preference satisfaction. In short, this implies that the moral good entails maximizing preference satisfaction, and that animal welfare holds that satisfying animal preferences will result in positive feelings. An animal can have a whole range of preferences to satisfy, including the preference to survive. If this latter preference is at stake, then (a) longevity should be included in the ethical assessment of animal welfare (cf. Singer, 1993) and (b) longevity can then be seen as a welfare issue since killing the subject results in the frustration of its preference and negatively affects the overall welfare.

Nonetheless, one can argue that the added value of longevity for the ethical discussion on welfare, and especially on premature killing, is still marginal for two reasons. First, the desire to stay alive is only but one possible preference that needs to be balanced against other preferences of the animal and those of other sentient beings involved. A reference to longevity as such is not a sufficient argument to understand or justify the moral intuition that premature killing is a moral wrong. This is related to the problem of comparing welfare states. However, at this point lifespan can make a genuine contribution. To judge what is better or worse in terms of (overall) welfare depends on what will happen in the future. An example is tail docking in pigs. Tail docking in pigs is performed regularly on pig farms even though many farmers do not have any experience with the problem of tail biting on their farm (De Lauwere et al., 2009). Although the occurrence of tail biting in the future is not a certainty, to prevent the detrimental effects of this behavior the tail is docked. The docking itself is painful, but it is not certain whether the procedure is needed to prevent the even more severe effects of tail biting. Citing examples like this one Yeates (2009) states: "It follows from this comparative nature of (at least much of) welfare assessment that the value of a welfare state may depend not only on what that state included in itself, but also on what states would otherwise be present." The assumption that animal welfare is more than only the feeling and interests of the animal in the present makes it possible to state that future welfare and future interests will be infringed when the animal is killed. Thus comparing different states of welfare includes more than the present state of the animal; it is also about what has been and what will be (Yeates, 2009). From this perspective longevity is more than merely an indicator or precondition of animal welfare. It is a way to grasp the future preferences of an animal in the process of comparing preferences.

The second reason that longevity is marginal to the ethical discussion on animal welfare is that the preference to stay alive and live a long(er) life relates to consciousness and to the capacity to have a minimum idea of concepts such as life, death, and the future. This confronts us with some serious empirical questions, i.e. is it possible to scientifically determine whether animals do have a future orientation and, if so, whether they prefer to stay alive? The answers to these questions are still uncertain. DeGrazia (1996), for example, argues that sentient animals have desires and that some of them have a sense of time in terms of a memory (sense of the past) or a sense of the future (anticipation). He emphasizes that the level of having desires and a sense of time can be different from that of humans but that the level is not decisive for acknowledging its moral importance. It is about whether there is some perception of time or not. If so, then the animal is not stuck in the present and will have interests in more than present experiences only. Based on empirical findings, there are indications that animals do have the capacity to have a future orientation. For instance, Kotler et al. (1999) showed that squirrels can balance present and future needs when foraging for food for the winter. Of course, this does not result in conclusive arguments on the capacities of other animals such as the cow with a foot disorder. However, there are two reasons why we may argue that such a cow can have preferences about her future. On the one hand, it is likely that a cow, a mammal as well, has similar cognitive capacities and therefore has a future orientation. On the other hand, even without conclusive evidence we have a strong moral reason to treat animals, such as cows, as having the capacity to have preferences about their future. This is justified based on a precautionary reasoning. The fact that there is a possibility that animals have some future orientation is enough to give the animals the benefit of the doubt. This illustrates that – even if we take the empirical uncertainty seriously with respect to animals' consciousness – longevity can serve as an independent moral argument in the animal welfare debate. The application of this view implies that if an animal has a sense of the future and if there is future welfare at stake, then this plays an important role in deciding whether to treat or to cull a cow. It is no longer possible to decide based on the present situation only. Culling a healthy cow then implies the risk of an affected welfare because the animal's potential preference for life will be affected and the possibility of satisfying future preferences may be frustrated. This also holds for a foot disorder that is likely to result in full recovery without a long and painful disease process. According to the view of preference satisfaction, the interests of the animal in terms of missed future welfare and the preference for life need to be weighed against the interests of the farmer. Compared to the above-discussed views on longevity, the premature culling of dairy cows needs justification because of the welfare impact of living a shorter life. Another consequence is that efforts to prevent and treat foot disorders have relatively more weight compared to the situation where longevity is only an indicator or precondition.

The importance of species-specific development. In the public debate animal welfare is not only framed in terms of functioning and feeling but it also includes the aspect of natural living. This entails the ability to perform natural behaviors and fulfill (behavioral) needs that are important to and characteristic of that species. At this point there has been a clear change in the perception and evaluation of animals. Cohen et al. (2007) state: “The relationship between man and animal has in recent years evolved from a purely functional relationship in which the animal is valued mostly for its instrumental utility to humans towards one in which respect for the value of the animal as a being in its own right plays a significant role.” For instance, the cow’s need to walk outside or the chicken’s need to have the opportunity to take a dust bath are considered to be essential elements for a good animal life and therefore necessary to justify animal use.

The focus on natural living is not restricted to the public debate. It can also be recognized in the research on animal welfare. The attention to natural living often starts in a view on welfare that integrally assesses the life of an animal. This implies that a focus on ‘mental state’ and subjective experiences are combined with objective characteristics of the quality of life (e.g., whether the animal is able to perform its species-specific behavior) and satisfaction of preferences during life. From this perspective, natural living implies that the animal has to be able to live according to its nature. In other words, the animal has to be able to perform species-specific behavior. To explain the notion of species-specific behavior, Fraser (1999) refers to the Aristotelian concept of telos that has been elaborated by Rollin (2004): “… animals have natures of their own (telos), and interests that flow from these natures….”

The emphasis on natural living has implications for the relevance and applicability of the notion of longevity as a welfare issue. The question is no longer whether animals suffer from an early death, but to what extent does an early death frustrate the aspect of natural living and the ability to perform species-specific behavior. An example of such a view is Nussbaum’s capabilities approach. She argues that humans and animals have certain species-specific goals and that these beings should be able to develop these specific abilities and skills in order to flourish and to live according to their telos. In this view longevity clearly becomes a welfare issue because the possibility of developing species-specific abilities refers not only to functioning and feeling in the present - as it is traditionally perceived in the functioning and feeling views - but it also refers to a certain lifespan. Welfare in terms of flourishing and living a life that is in line with the telos of that subject implies a welfare approach that assesses welfare over time and takes an integral perspective. The aspect of time emphasizes that welfare should be measured and assessed during a longer period rather than at single time points only. For example, an elephant’s long-lasting search for food or water in dry areas in order to survive involves discomfort but fits in the adaptive and natural capacities of the animal. Consequently, the elephant’s overall welfare over time might not be compromised because this search is needed to survive and it enables the animal to have positive welfare in the future and to develop characteristics needed to survive as an individual and as a species. Consequently, lifespan is a relevant welfare criterion. The integral perspective, in which more than only the functioning and feelings of the animals in the present is of importance, implies that the relevance of longevity is not restricted to the animals' capacity of being aware of their own future because flourishing is worthwhile striving for in itself. Because this implies a certain lifespan, longevity is a constitutive element of animal welfare.

For dairy farming this implies that longevity gets more weight in culling decisions about healthy cows and cows with a health problem. Farmers and their advisors are confronted with cases of foot disorders needing a diagnosis about treatability. Since this diagnosis is not value free, farmers can value the same situation differently. For example, one farmer might judge a lame cow with a sole ulcer not to be a real welfare problem for the animal and he would thus be less inclined to treat the cow quickly after having discovered it is lame. However, another farmer might recognize this as a welfare issue and take action. Sometimes there are clear cases in which all agree that the animal's welfare is affected very severely by the disorder and that the life of the animal cannot be improved by treatment. Then killing can be in the animal's interest whether you consider it from the perspective of biological functioning, feeling, or natural living. Based on the prima facie responsibility to kill an animal that would otherwise have a life worth avoiding (Yeates, 2009), it is necessary to know when there is no treatment or improvement possible in order to prevent the animal from suffering needlessly before being killed.

In other cases, the situation is more complicated because of the uncertainty about the need or the possibility of treating the animal. In those cases the broader view on welfare requires taking the aspect of longevity into account as an independent argument. The lifespan of the animals has to be weighed against different interests in animal food production. The interests of the animals get more weight if one starts from the assumption that an animal's ability for species-specific development should be taken seriously.

This could result in an increased age of dairy cattle because welfare that includes longevity is given more weight. This requires management and housing that improves prevention strategies and the treatment of health issues.[3] On top of this, this view meets the moral intuition that killing animals raises moral questions. From this perspective, there is a clear need to justify the culling of animals because the lifespan of the animals receives more value than in the more restricted views on welfare (functioning and feeling). Whereas in those restricted views culling healthy or treatable animals is not seen as a welfare issue for the individual animal, in the broader view culling affects the welfare of animals. This means that prematurely culling dairy cows for farm-technical reasons becomes an animal welfare issue even if the animal has no direct physical or mental discomfort. Based on this

[3] We are aware that if dairy cows are able to have a longer productive life, the bases and management of dairy farming need to be reconsidered to prevent potential other or new dilemmas. However, such dilemmas should not prevent us from discussing the role of longevity in the welfare of dairy cows.

view we can make a step from longevity as an indicator or as a precondition for animal welfare to the idea of longevity as a constitutive element of animal welfare. This, however, requires including the integral lifespan and the development and capacities of the individual animals in the welfare assessment.

Conclusion

We conclude that longevity should be considered as a constitutive element of animal welfare rather than as a mere indicator of animal welfare. We have shown that this view involves two steps.

The first step is moving from welfare as a concept based mainly on biological knowledge to the notion that animal welfare is based on and informed by biological knowledge but is equally driven by moral norms. Consequently, what we owe to animals can be interpreted more broadly than merely preventing physical or mental discomfort (views on functioning and feeling). It also includes the duties to enable animals to flourish and live a natural life, which comes with an emphasis on longevity.

A second step is moving from views on animal welfare in terms of functioning or feeling well to a view on animal welfare that includes the aspect of natural living in which species-specific preferences and species-specific development are important. We argue – by using both normative and biologically based arguments - that animal welfare should be approached more integrally and that it should be assessed over time. Therefore, the animals' adaptive and natural capacities should be a key element in defining welfare rather than a single focus on the animals' functioning or feelings at a certain moment.

This point of view allows us to evaluate the welfare of animals from the perspective of the whole lifespan of an animal. This interpretation is independent of the capacity to comprehend life or have a future orientation. It is important that animals are able to live a life in which they can adapt to fulfill their preferences and show species-specific behavior.

In the public debate on animal husbandry, this view enables us to understand and address the moral intuition that killing animals includes a moral wrong even if the act of killing is performed in a welfare-neutral way. Longevity as a welfare issue shows that killing should not only be evaluated from the perspective of the direct act but should also take the future abilities to flourish into account.

In the practice of dairy farming, considering longevity as a welfare issue can be a useful tool in assessing welfare and managing foot disorders in dairy cattle. It implies that premature culling, i.e. culling the animal before the end of a normally intended productive life, is not a neutral act but one that can affect animal welfare because of its implications for the longevity of a cow. This broadens the scope of evaluating foot disorders. Rather than merely focusing on whether a foot disorder is evaluated in terms of the cow's ability to function in a certain system, this view requires an assessment in which all the interests of an animal, including those related to lifespan, are taken seriously.

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Chapter 6

Dairy farmers' attitudes and intentions towards improving dairy cow foot health

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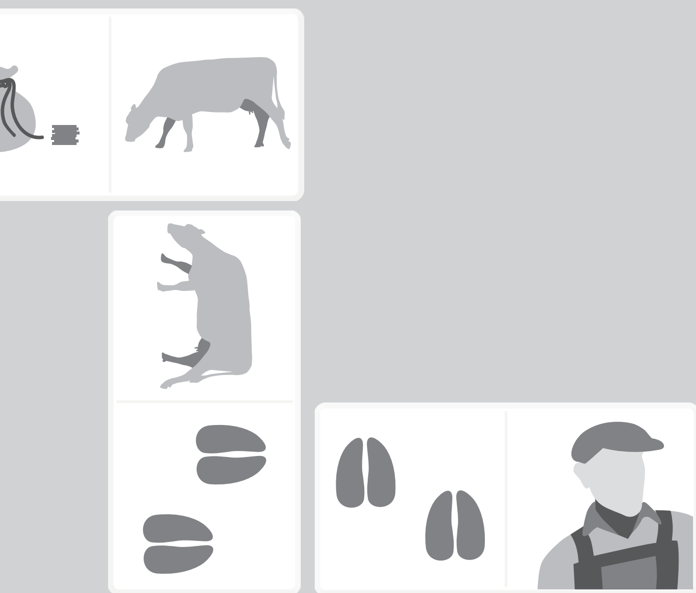

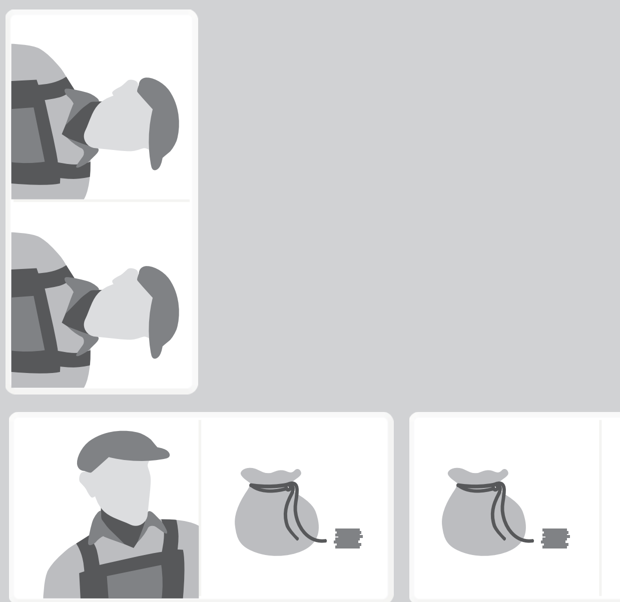

Abstract

Dairy cow foot health is a subject of concern because it is the most important welfare problem in dairy farming and causes economic losses for the farmer. In order to improve dairy cow foot health it is important to take into account the attitude and intention of dairy farmers. In our study the objective was to gain insight into the attitude and intention of dairy farmers to take action to improve dairy cow foot health and determine drivers and barriers to take action, using the Theory of Planned Behavior. Five hundred dairy farmers were selected randomly and were invited by email to fill in an online questionnaire. The questionnaire included questions about respondents' intentions, attitudes, subjective norms and perceived behavioral control and was extended with questions about personal normative beliefs. With information from such a framework, solution strategies for the improvement of dairy cow foot health can be proposed. The results showed that almost 70% of the dairy farmers had an intention to take action to improve dairy cow foot health. Most important driver seems to be the achievement of better foot health with cost-effective measures. Possible barriers to taking action were labor efficiency and the effect of achieving an improved dairy cow foot health a long time after taking action. The feed advisor and foot trimmer seemed to have most influence on intentions to take action to improve dairy cow foot health. Most farmers seemed to be satisfied with the foot health status at their farm, which probably weakens the intention for foot health improvement, especially compared to other issues which farmers experience as more urgent. Subclinical foot disorders (not visibly lame) were not valued as important with respect to animal welfare. Furthermore, 25% of the respondents did not believe cows could suffer pain. Animal welfare, especially the aspect of providing good care for the cows, was valued as important but was not related to the intention to improve dairy cow foot health. The cost-effectiveness of measures seemed to be more important. Providing more information on the effects of taking intervention measures might stimulate farmers to take action to achieve improvement in dairy cow foot health.

Key words: dairy cow foot health, dairy farmer, intention, Theory of Planned Behavior, animal welfare, economics

Submitted to Livestock Science

Introduction

The foot health status of dairy cattle is a subject of concern because poor foot health is considered to be the most important welfare problem in dairy farming and causes substantial economic losses to the farmer (Algers et al., 2009; Bruijnis et al., 2010). However, the occurrence of foot disorders and the resulting lameness have not decreased despite much knowledge having been gained over the years (e.g., Bell, 2005; Barker et al., 2010). There is a diversity of foot disorders, all having their own characteristics for severity, duration and incidence (Algers et al., 2009). Therefore, the impact of the foot disorders on dairy cow welfare and economic consequences for the dairy farmer are specific for each foot disorder. Although risk factors and possible intervention strategies are known and applicable, many farmers do not implement intervention strategies (Bell et al., 2009). An important reason for this might be underestimation of the scale of the problem and the effect on economics and animal welfare (Leach et al., 2010). In a situation where one does not perceive a problem, it is not likely that the person will take action to improve the situation.

Farmers play a key role when it comes to improvement of dairy cow foot health as they are responsible for their cows and make decisions about housing and management. To find a solution or an improved approach on foot disorders in dairy cattle, it is important to include the attitude of the dairy farmer as attitude influences behavior (Ajzen and Fishbein, 1980). Theories developed in social sciences offer opportunities to gain more insight into the attitude of dairy farmers concerning improvement of dairy cow foot health. Several studies have used social theories for animal health issues in animal production, for example Garforth et al. (2006) using the Theory of Reasoned Action to determine farmers' attitudes about measures to increase estrus detection in dairy cows, Huijps et al. (2009) using Adaptive Conjoint Analysis to explore differences between personal preferences concerning measures to improve udder health and Ellis-Iversen et al. (2010) using a theoretical framework from behavioral science about zoonotic control programs. These studies show that such approaches can contribute to a reduction of the scale of a health problem, as Jansen et al. (2010) did in the context of a mastitis control program. These examples show that a behavioral approach can be valuable for addressing the problem of foot disorders in dairy cattle. The objective of our study was to gain insight in the attitude and intention of dairy farmers to take action to improve dairy cow foot health and determine drivers and barriers to taking action. With such information solution strategies for the improvement of dairy cow foot health can be developed because attitude and intention are found to be important to promote behavior changes (Rehman et al., 2007; Jansen et al., 2009).

Material and Methods

For our study we used an internet questionnaire to collect data on the attitude and intention of dairy farmers about improving dairy cow foot health. This questionnaire was based on a theoretical framework and provided quantitative data. Afterwards, in-depth interviews were held among nine of the respondents of the questionnaire to explore in more detail the reasoning behind responses given in the questionnaire.

Theoretical framework

The theoretical framework for the main body of the data collection is based on the Theory of Planned Behavior, which is an extension of the Theory of Reasoned Action (Ajzen and Fishbein, 1980; Ajzen, 1991). The theory assumes rational behavior and the intention of a person to perform a certain behavior is assumed to be influenced by their attitude (A), subjective norm (SN) and perceived behavioral control (PBC). The behavior of interest in this study is to take action to improve dairy cow foot health. The attitude towards this behavior is determined by the beliefs about possible effects of performing the behavior (outcome belief) and the value one gives to this effect (outcome evaluation). The subjective norm is determined by the perceived level of support of the salient referents with respect to improvement of dairy cow foot health (social normative beliefs), and the motivation to comply with these referents (motivation to comply). The perceived behavioral control is determined by the belief to have resources available (control belief strength) and the importance of these resources (control belief power). Resources refer to the availability of knowledge, finances, time and labor. We extended the framework by asking questions concerning personal normative beliefs (PNB), which tell more about their personal values regarding animal welfare and moral obligations towards animals. Such beliefs can increase the value of the model (Ajzen, 1991). This resulted in our extended framework of the Theory of Planned Behavior (Figure 1). A significant positive correlation between the attitude, subjective norm, perceived behavioral control and the intention indicates a cognitive driver. A significant negative correlation indicates a cognitive barrier (Garforth et al., 2006).

The questionnaire

The first step to construct the questionnaire aimed at defining outcome beliefs and control beliefs of dairy farmers regarding dairy cow foot health and salient referents who influence farmers' decisions. In order to find these beliefs and referents, baseline studies (unpublished data from surveys held in The Netherlands) about dairy cow foot health were used. Based on ethical principles questions about the personal normative beliefs were formulated (see summary in Table 1).

The first part of the questionnaire consisted of general questions about the farm (7 questions about number of cows, housing system, etc.). The second part concerned the importance of dairy cattle foot health in general and developments and importance of foot health on the farm (15 questions about foot health status, management around foot health, the importance of foot health problems, etc.). The third part consisted of questions based on our theoretical framework (Figure 1). The items for A (16 questions), SN (16 questions), PBC (6 questions) and PNB (9 questions) were measured on 7-point bipolar ordinal scales (-3 to +3). Some questions, like the intention question and the question on the farmer's ability to achieve improvement in dairy cow foot health were asked on a scale from 1 to 10. The questionnaire ended with the opportunity to give some additional remarks, some personal details (5 questions) and the ability to sign up to win a gift voucher (3 vouchers were randomly drawn from the completed questionnaires).

From the farmers that are member of Netherlands' largest dairy company (FrieslandCampina, Amersfoort, The Netherlands), 500 were randomly selected and received an email from FrieslandCampina with a link to the online questionnaire and the recommendation to fill in the questionnaire. The email included an explanation letter written by the authors as well. The questionnaire was launched on November 18th, a reminder was sent on December 5th and the questionnaire was closed at December 16th 2011. Afterwards, nine farmers were interviewed using a semi-structured interview to gain more insight into the underlying reasons and motivations. These farmers were selected based on differences in farm size, milk production, stated importance of foot health and intention to improve dairy cow foot health.

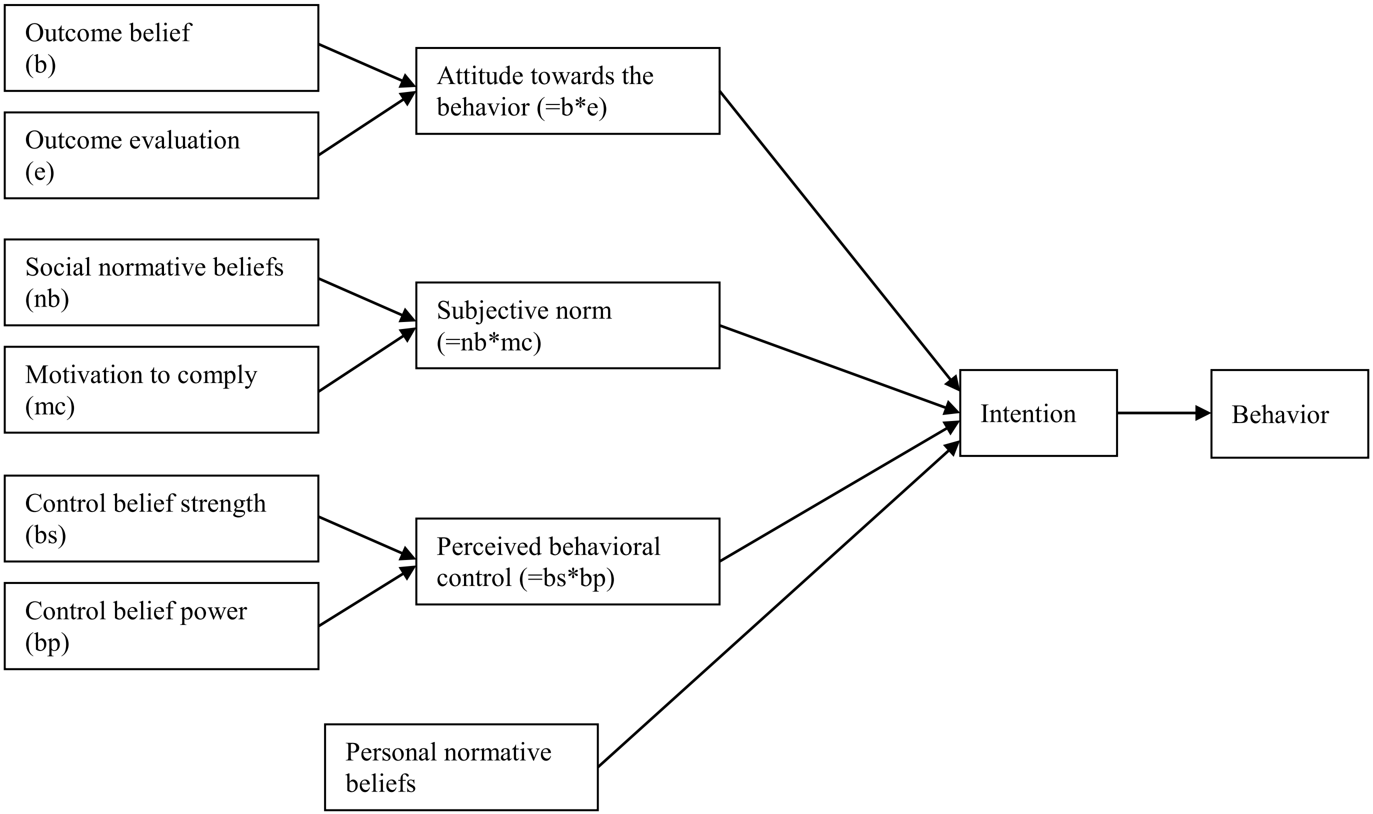

Figure 1. Schematic presentation of the Theory of Planned Behavior, extended with personal normative beliefs.

Table 1. Overview of the items asked in the different parts of the questionnaire using the framework based on the Theory of Planned Behavior

Attitude (including outcome belief and outcome evaluation)
Action to improve dairy cow foot health …
… results in better foot health
… can be achieved with cost-effective measures
… can be labor efficient
… can have effect in short term
… results in a higher income
… contributes to job satisfaction
… increases milk production
… improves dairy cow welfare

Subjective norm (including social normative belief and motivation to comply)
Salient referents:
-feed advisor
-foot trimmer
-veterinarian
-trade journals
-colleagues or study group
-Animal Health Service
-society
-family and friends

Perceived behavioral control (including control belief strength and control belief power)
Resources needed to take action:
-knowledge
-financial resources
-time and labor

Personal normative beliefs
A cow can suffer pain
A dairy farmer has the duty to take good care for his cows
A cow only has value as production unit
A cow has a value independent from production
The welfare of a cow is important for the choice whether or not to treat a cow
A cow has a right to life
It is acceptable to cull a cow only after a cow has been treated
It is important to decide autonomously what is good for my cows

Data analysis

Data were organized and analyzed using Statistical Package for the Social Sciences (SPSS, version 19). The questionnaires of respondents who did not fill in all the questions based on the theoretical framework were deleted, as well as the respondents giving unrealistic answers. In order to check the internal consistency of the item scales used for the different variables (A, SN and PBC) of the Theory of Planned Behavior, the Cronbach alpha coefficient was calculated. A high Cronbach alpha (>0.6) indicates that the products of the different items can be summed to the calculated attitude, subjective norm and perceived behavioral control. Otherwise the items can only be used separately to calculate correlation coefficients. The associations between the elements in our framework were assessed based on Spearman rank correlation coefficients (r_s). To determine differences between different groups (e.g., age or gender) with intention within our study population the Mann-Whitney U test (for comparison of 2 variables) or a Kruskal-Wallis test (comparison of 3 or more variables) were executed (Baarda et al., 2004). In a situation where the data are measured along an ordinal scale data are not likely to conform to normal distribution assumptions (as in our case). For these reasons non-parametric tests were preferred as these are generally acknowledged to give more robust results than parametric tests (e.g., Garforth et al., 2006).

Results

Study sample and farm characteristics

Of the 500 farmers approached, one farmer appeared to have stopped farming. Of the remaining 499 farmers 152 (30%) filled in the questionnaire, with a mean age of 45 years. Most respondents were male (93%). Average herd size was 85 cows per farm (median=78, Dutch average = 76 cows (LEI, 2011) with an average milk production of 8,519 kg/yr (Dutch average = 7,900 kg/yr (LEI, 2009). Most farms applied pasturing (78%; compared to 74% in The Netherlands (CBS StatLine, 2010)), used Holstein Friesian cows (89%) and cubicle housing (95%, Dutch average = 93% (CBS, 2008) the latter mostly with a concrete floor (97%). One farm was organic.

Dairy cow foot health

Only 6% of the respondents indicated that the foot health at their farm was worse than average, while 65% indicated an average foot health at their farm. Almost half (48%) indicated foot health had improved during the last 5 years. On average, farmers indicated that 22% of their cows had a foot disorder in one year (range 0-86%), where most farmers (almost 70%) used, at least, locomotion of the cows to determine the number of cows with a foot disorder. Of the management practices listed in the questionnaire, 64% applied foot bathing and 86% applied foot trimming on a regular basis. Most important risk factors for foot disorders according to the respondents were feed (51%) and flooring or path (29% or 28% respectively) while lying place was mentioned least frequently (8%). Of the measures to improve dairy cow foot health, the intention to check the cows more often was chosen most often (28%), followed by adjusting breeding management (24%) and improved foot bath management (17%) and feeding ration (16%) (Table 2). Sole ulcer and digital dermatitis were mentioned as most frequent occurring foot disorders (74 and 72% respectively), interdigital dermatitis and heel erosion and interdigital phlegmon were least present according to the respondents (30 and 32% respectively).

Intention to improve dairy cow foot health

Of all the 152 completed questionnaires seven were deleted because of incomplete answers for the questions based on the framework or because of inconsistent answers. The scales of the items for the A and SN were consistent (Cronbach's alpha > 0.6), which indicates the scales for items for these variables were internally consistent and could be aggregated. For PBC the item scales were not consistent. Although these items were not relating to the same content of the PBC, separately the items do relate to a specific aspect of the PBC. Therefore, these items were not combined and only correlated separately with the intention.

The intention did not differ for the following groups within the population: age of the farmer, young (age 24-44) versus old (age 45-65) ($U=2,490$; $p>0.05$); milk production, high producing (>8,500 kg/cow/yr) versus low producing (≤8,500 kg/cow/yr) ($U=2,298$; $p>0.05$); gender, men versus women ($U=622$; $p>0.05$); farm size, small farms (<80 cows) versus large farms (≥80 cows) ($U=2,405$; $p>0.05$).

Of all the 145 valid responses, 66% stated they had intention to take action to improve dairy cow foot health (intention>6; scale 1-10; mean=6.77; SD=2.57), where 47% had a strong intention (intention>7) to improve dairy cow foot health.

Importance of foot health and dairy cow welfare

On average farmers rated the problem of foot disorders as moderately important (mean=6.32; scale 1-10; SD=1.92). The intention to take action for foot health improvement was associated with this attitude ($r_s=0.18$; $p<0.05$). The estimation of farmers about their dairy cow foot health status compared to other farms in The Netherlands was associated with the intention as well: if a farmer stated his cows have a good foot health status, the intention was lower compared to farmers who stated their cows perform less well than other farmers ($r_s=0.45$). The development in foot health status during the last 5 years was not correlated with the intention, however, there was a difference in intention for people who indicated the foot health status had worsened compared to the people who thought it had improved (mean rank score=97.3 compared to 71.9; Kruskal-Wallis test

Chi^2=11.3; df=2; p<0.005). Furthermore, if a farmer believed the foot health status had become worse during the last 5 years, it was likely the farmer also thought that the current foot health status was below Dutch average (r_s=0.32; p<0.01). The belief about the foot health status at their own farm was not associated with beliefs about the importance of foot disorders for the whole dairy farming sector. The intention was associated with the number of measures one intended to apply; the more measures one was intending to apply, the higher the score for the intention question (r_s=0.29; p=<0.01). The perceived cost-effectiveness of measures was associated with the number of intended measures (r_s=0.22; p<0.01) while beliefs about health and welfare were not associated with intention or cost-effectiveness (Table 2). Beliefs about improvement of foot health and welfare were associated with each other (r_s=0.51; p<0.01). In contrast, while no association was found between the intended measures to apply and the belief that those measures would improve welfare, there was an association between the overall intention to take action to improve foot health and attitude towards welfare outcomes (Table 3). Of the PNB, the provision of good care was valued highest (mean=2.70). The questions about value of the animal as production unit and the intrinsic value of the cow (value of the cow independent from production or usefulness) had mean values of 1.13 and 1.36 respectively (Table 6) and were not negatively associated with each other. The respondents indicated that a clinical foot disorder affects dairy cow welfare (mean=7.92; 89%>6; 71%>7) and that a subclinical foot disorder does not really affect welfare (mean=4.15; 11%>6; 4%>7). Most farmers believed that cows could suffer pain (70%), however, 25% of the farmers did not believe that cows could suffer pain. The value for welfare impact of clinical foot disorders was associated with intention (r_s=0.25; p<0.01) and with the belief about importance of the problem of foot disorders in dairy farming (r_s=0.36; p<0.01).

Table 2. Different interventions to improve dairy cow foot health and the percentages for the number of farmers intended to apply the measures, the number of farmers believing the measures is cost-effective, improves dairy welfare and improves dairy cow foot health

Measure	Percentage of farmers (%)			
		Belief to …		
	Intended to apply	…be cost-effective	…improve dairy cow welfare	…improve dairy cow foot health
Use rubber flooring in the walking alleys	2.1	10.3	46.9	31.7
Reduce stocking density	13.8	9.0	53.8	24.8
Improve lying places	13.1	11.0	53.1	21.4
House dry cows in straw yard	7.6	5.5	48.3	21.4
Improve floor hygiene	10.3	15.9	32.4	47.6
Improve foot bath management	16.6	22.1	20.0	42.8
Improve foot trim management	13.1	18.6	30.3	43.4
Improve feeding ration	16.6	26.2	31.0	36.6
Adjust breeding strategy	25.5	31.0	31.7	45.5
Increase frequency of checking the cows	29.7	20.0	42.8	36.6

Table 3. The mean values and correlation with intention for the attitude towards the behavior 'Taking action to improve dairy cow foot health', including outcome beliefs and outcome evaluations (scale -3 to +3)

Attitude items (n=145)	Outcome belief (b)		Outcome evaluation (e)		Outcome attitude (b)*(e)	
	Mean	Correlation with intention	Mean	Correlation with intention	Mean	Correlation with intention
Results in better foot health	0.86	0.42**	1.59	0.38**	2.19	0.39**
Can be achieved with cost-effective measures	1.20	0.27**	1.94		2.68	0.27**
Can be labor efficient	-0.57	-0.12**	2.03	0.22**	-1.00	
Can have effect in short term	-1.10	-0.33**	1.15		-1.22	
Results in a higher income	1.13	0.28**	1.16		1.84	
Contributes to job satisfaction	2.20		2.46		5.62	
Increases milk production	1.54	0.35**	1.58		2.64	0.18 *
Improves dairy cow welfare	1.67	0.34**	2.30		3.94	0.33**
Calculated attitude (∑(b*e): range -72 to +72)					16.70	0.30**

* $p<0.05$, ** $p<0.01$

Attitude, subjective norm and perceived behavioral control

Of the attitude items (Table 3), job satisfaction received highest scores of all the attitude items (mean=2.20 for outcome belief and mean=2.46 for outcome evaluation). Furthermore the welfare of the cow was scored as important (mean=2.30) and the labor efficiency and perceived cost-effectiveness of taking action had a high outcome evaluation as well (mean=1.94 and mean=2.30 respectively). On average, a negative value was given for the belief about labor efficiency (mean=-0.57) and being able to achieve an improved dairy cow foot health in short term (mean=-1.10). Of the salient referents, the foot trimmer, veterinarian and feed advisor were valued highest for both social normative belief and motivation to comply (Table 4).

The belief that one would really achieve an improved foot health by taking action was not very high (mean=0.86) but was associated relatively strongly to the intention. Together with cost-effectiveness, increased milk production and improved welfare, the belief to achieve an improved foot health could be a cognitive driver to take action (see correlations in Table 3). However, on average more than 60% stated that they would be able to improve dairy cow foot health (mean=6.72; scale 1-10; SD=1.57), and for the people who intended to improve foot health this was 72%. The belief about labor efficiency and effect in short term were negatively associated with intention, high labor input and result in long term are possible cognitive barriers to taking action. Job satisfaction, which received the highest values among the attitude items, was not associated with the intention to take action (Table 3).

The correlations of the items of SN with intention (Table 4) identify possible cognitive drivers. These results showed that the feed advisor and the foot trimmer can be cognitive drivers. The veterinarian was valued as supportive as well but was only associated with the intention for the aspect to follow their advice. The people from outside dairy farming, society and family and friends, were not experienced as supportive and there was no motivation to comply with society (mean=-0.92). Farmers were motivated to comply with colleagues' advice but colleagues were not perceived to be very supportive about foot health improvement (social normative belief; Table 4). The calculated A and SN did not correlate with intention. For PBC knowledge was thought to be important (mean=1.15) and available (mean=1.79), and showed an association with the intention, indicating it as a possible driver. Financial resources were valued as important (mean=1.20); however, the availability was indicated to be insufficient (Table 5).

Table 4. The mean values and correlation with intention for subjective norm for 'Taking action to improve dairy cow foot health', including social normative belief and motivation to comply (scale -3 to +3)

Referent (n=145)	Social normative belief (nb)		Motivation to comply (mc)		Subjective norm (nb)*(mc)	
	Mean	Correlation with intention	Mean	Correlation with intention	Mean	Correlation with intention
Feed advisor	1.13	0.29**	1.28	0.24**	2.45	0.23**
Foot trimmer	1.62	0.24**	1.67	0.19 *	4.41	0.20 *
Veterinarian	1.37		1.57	0.17 *	3.10	
Trade journals	0.21		0.37		0.96	
Colleagues / study group	0.07		0.70	0.18 *	1.10	
Animal Health Service	0.04		0.22		1.50	
Society	-0.92		-0.08		1.57	
Family and Friends	-0.70	0.18 *	0.10	0.19 *	1.21	
Calculated subjective norm (Σ(nb*mc): range -72 to 72)					16.29	

* p<0.05, ** p<0.01

Table 5. The mean values and correlation with intention for perceived behavioral control for 'Taking action to improve dairy cow foot health', including control belief strength and control belief power (scale -3 to +3)

Ability (n=145)	Control belief strength (bs)		Control belief power (bp)		Perceived behavioral control (bs)*(bp)	
	Mean	Correlation with intention	Mean	Correlation with intention	Mean	Correlation with intention
Knowledge	1.79		1.15	0.16*	2.19	0.20*
Financial resources	-0.19		1.20		-0.88	
Time and labor	1.26		0.64	0.17*	0.53	

* $p<0.05$, ** $p<0.01$

Table 6. Means of the personal normative beliefs (personal values about animal welfare and moral obligations) (scale -3 to +3)*

Animal welfare and ethical values (n=145)	Mean (SD)
A cow can suffer pain	1.28 (2.14)
A dairy farmer has the duty to take good care for his cows	2.70 (0.79)
A cow only has value as production unit	1.13 (1.72)
A cow has a value independent from production	1.36 (1.26)
The welfare of a cow is important for the choice whether or not to treat a cow	1.66 (1.56)
A cow has a right to life	1.83 (1.24)
It is acceptable to cull a cow only after a cow has been treated	2.01 (1.26)
It is important to decide autonomously what is good for my cows	1.90 (1.10)

* None of the values was correlated with the intention to improve dairy cow foot health.

Discussion

This study obtained new insight into the attitude of dairy farmers concerning dairy cow foot health and their intention to improve dairy cow foot health. The study sample appeared to be representative for the Dutch situation as the milk production level, number of cows per farm, breed and housing type represented the most common type of dairy farm in The Netherlands. Most respondents were male and a comparison between men and women showed no difference in intention. One reason for this could be explained by the fact that farmers often filled in the questionnaire together with their partner, as appeared during the in-depth interviews. Furthermore, Kauppinen et al. (2012) also found no gender effect and stated that it is more likely that within gender more differences will be found. It is likely that intention for improvement is possibly more determined by personal characteristics. This statement is supported by the fact that within the responses a large variation can be seen for the importance given to foot disorders and intention to improve dairy cow foot health. These personal characteristics are not likely to relate to socio-demographic aspects, as comparisons between groups of different age, farm size and production levels did not give significant differences.

Almost 70% of the respondents had an intention to improve dairy cow foot health. And, it was promising that most of these farmers indicated that they would be able to achieve improvement. However only 47% expressed a strong intention (score >7) to take action to improve foot health. There are different potential reasons for the moderate intention to improve dairy cow foot health. Firstly, it could be that farmers have taken certain measures already, to a certain extent, which was reflected in the number of measures farmers indicated they intended to apply. Secondly, some farmers do not intend to take measures at all because they are satisfied with the current housing and management. Satisfaction with the current situation seems to relate to an underestimation of the scale and impact of foot disorders (Leach et al., 2010). This underestimation might be explained partly by the fact that most farmers think that only clinical foot disorders have an effect on animal welfare, while almost half of welfare impact is in fact caused by subclinical foot disorders (Bruijnis et al., 2012). This can also explain why interdigital dermatitis and heel horn erosion (IDHE) was indicated to have low prevalence, while the presence of subclinical IDHE is estimated to be high in literature (Somers et al., 2003; Frankena et al., 2009).

Despite the finding that 25% of the respondents did not believe that cows suffer pain, 70% thought a cow could suffer pain. This probably only applies to the clearly visible clinical cases, while bilateral or subclinical foot disorders are not recognized and not seen as a problem. It is likely that when a farmer recognizes less intensive pain as important for animal welfare, this will have a positive effect on the attitude to improve foot health, as Kielland et al. (2010) showed that agreement with the statement that animals experience pain as humans (showing empathy with animals) was associated with lower prevalence of skin lesions. Cow comfort seemed not to play a key role in decisions to take measures for improvement (in-depth interviews). The view one holds on what animal welfare entails will influence the decisions on taking measures. The aspects as described by Fraser et al. (1997), functioning and health, feeling and natural living are valued differently by different groups of people (e.g., De Greef et al., 2006). The effect of measures on cow comfort and, with that on the feelings aspect of animal welfare, might be underestimated or neglected by a view on welfare mainly focusing on functioning and health. The view on functioning is mainly held by farmers (Te Velde et al., 2002), which is also shown in the results of the questionnaire as farmers expressed greater intention to consider cost-effective measures than the measures which were believed to improve welfare. Although this suggested that farmers are aware that welfare is more than good functioning and health, these aspects are valued as less important than costs. The welfare aspects of feeling and possibility to perform natural behaviors were not an issue during the in-depth interviews and the measures providing more comfort and that are expected to improve welfare (but not being cost-effective or improving foot health) were not associated with the intention, which indicates a minor role for animal welfare. Another question in the questionnaire showed a different picture than the in-depth interviews on the interpretation of animal welfare compared to the question about measures: 65-70% of the respondents ticked the two boxes on feeling and natural behavior as being part of welfare. Whereas, for example, Te Velde et al. (2002) showed that farmers mainly look at functioning and health as important for animal welfare while society tends to value naturalness and feelings of the animal as more important. It is likely that socially desirable answers explain this difference, the boxes about feeling and natural behavior are ticked pretty easily. Indication for socially desirable answers is also given by the unexpected values for the value of an animal as production animal and the cow having intrinsic value. Reversed associations were more logical than the lack of association with both having high mean values. Moreover, all the questions about the cow and care for the cow had positive mean values.

Thirdly, the moderate intention to take action might furthermore be explained because the suggested measures did not fit in their current farm management. On the one hand this could be caused by the fact that foot disorders are less important than other health issues at the farm. Udder health, which more directly relates to product safety and quality and where penalties are given, will have a higher priority than foot health. On the other hand the idea of incurring costs and changing labor efforts might play a role in the reluctance to take the presented measures seriously. The indicated belief to have enough financial resources probably applies to the more conventional and easier to apply measures such as feeding and breeding management. This is especially the case when the positive effects on foot health are not proven convincingly. Possibly, the behavior of farmers is not completely rational as assumed in the Theory of Planned Behavior, and cognitive dissonance may play a role in this aspect as well. Farmers may believe that they do and have done enough and that more action does not result in an improvement of foot health status or enough improvement compared to the investment of time, money or labor (Wassink et al., 2010). This is illustrated by an in-depth interview with one of the respondents. Despite the fact he was not satisfied with the foot health at his farm, he did not intend to take measures other than easy to implement and perceived cost-effective measures such as feeding and breeding. Measures needing more investment or change of system or labor input, for example improved cubicles or flooring, which also might improve cow comfort and welfare, are often not considered as an option, while in literature these aspects are mentioned as important factors regarding dairy cow lameness (e.g., Cook and Nordlund, 2009).

Compared to our previous model study about intervention strategies (Bruijnis et al., accepted) the ideas of farmers differ about cost-effectiveness. For example, in our study improved lying surface and improved foot trimming were found to be cost-effective while especially relatively few farmers believe that improved lying surface will be cost-effective, foot trimming is estimated to be cost-effective by more farmers. Stocking density, a measure estimated to be break even by Bruijnis et al. (accepted) scored the second least on cost-effectiveness in our questionnaire. Furthermore, foot bathing, one of the most costly interventions as shown in our study (mainly because of labor) was estimated to be cost-effective by relatively many farmers. It seems that such conventional, known measures are perceived to be the most logical options. More research which proves the positive effect of changing management and housing can help in convincing the farmer to choose measures which are not the ones already performed. Besides the aspect of proving effectiveness of less popular measures, it is important to pay attention to cognitive drivers such as job satisfaction, financial impact and impact on dairy cow welfare. Job satisfaction is valued as highly important by the farmers. Therefore, stressing the positive effects of taking action on job satisfaction could help, like showing the effects which are mentioned to be important for job satisfaction, for example, that cows will perform better and will have fewer problems. Hopefully such information will decrease the labor barrier, which also might be explained by a reluctance to change the daily routine (Huijps et al., 2009). Furthermore, a change of labor input or the extra investment of labor might be too demanding when weighted against the expected result; for example, sheep farmers were more willing to apply flock measures than individual treatments (Wassink et al., 2010) indicating a preference for measures which are less time consuming per animal and which can be executed at a convenient time. Advice on how to take specific measures is maybe more valued than an opinion about farming or long term solutions, especially because the time needed to achieve results is a barrier. For all advice to the farmer a ‘one-size-fits-all’ solution is not appropriate (Elliott et al., 2011), but an approach taking into account the circumstances where certain measures can be applied best, is more likely to be effective. The association between attitude and intention and between knowledge and intention is promising as it suggests that information directed at changing farmers’ understanding of the foot health situation might have a positive impact on intention and, consequently, behavior; e.g., results suggest some complacency about foot health status situation that could be addressed by stressing the negative effects of poor foot health and the positive outcomes of doing something about it. This idea is strengthened by the fact that knowledge seems to be a driver to take action. Furthermore it is notable that in our study the colleague farmers are not seen as important when it comes to improvement of foot health, while this was the case in other studies (Garforth et al., 2006; Elliott et al., 2011). The most important referents, feed advisor, foot trimmer and veterinarian, can have a role in the information delivery and motivating the farmers. An important point of attention in that case is to make sure these advisors are really critical and point out the positive effects of certain, less conventional, measures and also change their priority setting with respect to dairy cow foot health and attitude towards animal welfare.

Conclusion

Almost 70% of the dairy farmers in the study expressed an intention to take action for improving dairy cow foot health. Most important drivers seemed to be the achievement of better foot health with cost-effective measures. Possible barriers to taking action were the labor efficiency and the effect of achieving an improved dairy cow foot health a long time after taking action. The feed advisor and foot trimmer seem to have most influence on intention to improve dairy cow foot health. Farmers indicated they have enough knowledge as well as time and labor to achieve an improvement in dairy cow foot health. However, they indicated they have insufficient financial resources while they also indicated that foot health improvement can be achieved with cost-effective measures. The type of investment, the impact on labor demand or the idea that some of the mentioned measures will not have sufficient effect might explain this apparent inconsistency. Furthermore, most farmers seemed to be satisfied with the foot health status at their farm, which probably weakens the intention for foot health improvement, especially compared to other issues which are experienced as more urgent. Only clinical foot disorders were believed to really affect welfare, where 25% of the respondents did not believe cows can suffer pain. Animal welfare was mainly interpreted as providing good care for the cows resulting in good health and functioning of the cow. Animal welfare was stated to be important but was not related to the intention to improve dairy cow foot health. Cost-effectiveness seemed to be more important. Providing more information on the effects of taking action might stimulate farmers to take action to achieve improvement in dairy cow foot health.

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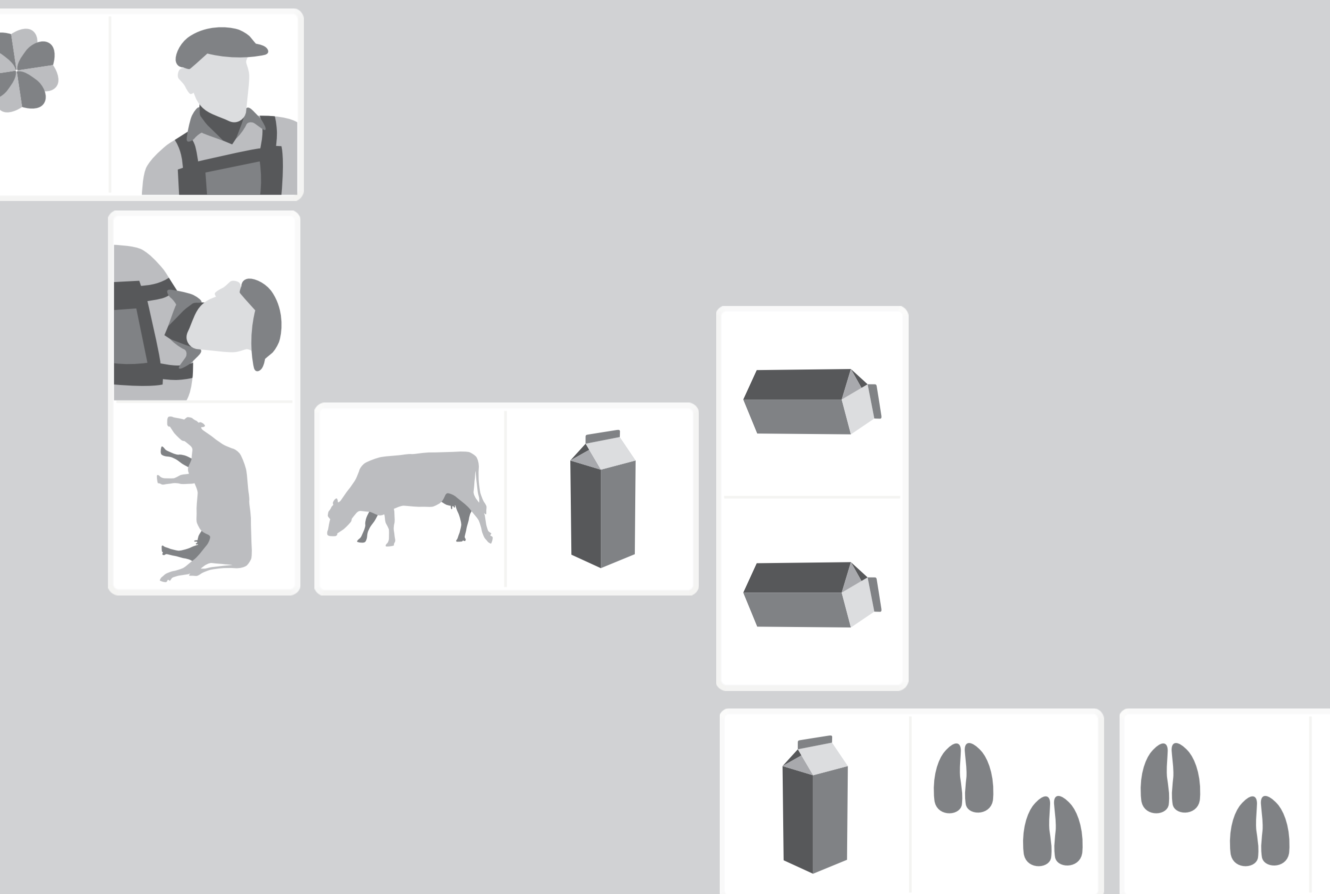
Chapter 7

General discussion



The aim of this thesis was to increase the awareness about the problem of foot disorders in dairy farming. A socio-economic approach was used to gain insight into this welfare problem and find strategies to improve dairy cow foot health. The research in this thesis consisted of two parts. One part, based on a newly developed simulation model on the presence and severity of foot disorders, aimed at gaining more insight into the consequences of foot disorders and the intervention measures to improve dairy cow foot health. Aiming at both the consequences for the farmer, in terms of economic losses, and consequences for the dairy cow, in terms of animal welfare. The other part aimed at the social and moral aspects. This part included a discussion about the concept of animal welfare where the question was asked whether longevity is an issue of animal welfare. Followed by a study into the attitude of dairy farmers with respect to dairy cow foot health and the intention to take action for its improvement. In this final chapter the findings in the different chapters will be discussed and give input to an analysis about the role of the dairy farmer. What can we reasonably expect from dairy farmers with regard to dairy cow foot health? This chapter will end with the main conclusions and recommendations.

The modeling approach

In this thesis a modeling approach has been chosen to gain insight into the problem of foot disorders as modeling is an appropriate method to achieve that aim. Modeling generates more profound and detailed insight into a problem than a literature study but is less intensive, costly and time-consuming than doing a study based on collecting and analyzing farm data. A literature study alone did not provide enough information to obtain thorough insight into the effects of foot disorders, therefore literature was used as input to model the different aspects. Modeling gives a more profound insight because the modeling simulates the situation and forces to include many different aspects. These results give suitable information for decision support. A study on gathering and analyzing farm data was practically and financially not feasible. Besides, it is uncertain whether another field study would have generated more valuable data than already available in literature, because still the disadvantages of a limited sample would have been present.

The use of modeling is nowadays very common and proven to be useful, both for assessing economic effects (e.g., Cicia et al., 2003; Halasa et al., 2009) using bio-economic modeling, as for the effect of housing systems on dairy cow welfare (Ursinus et al., 2009) using semantic modeling. Models help to gain insight in complex processes and help to describe and structure data. This makes it a useful tool to understand mechanisms, processes, but also to simulate scenario's to support decisions, even when information is incomplete (Singer et al., 2011). In this research a dynamic stochastic Monte Carlo simulation model has been developed. This means that this model simulates changes over time (dynamic), includes variation (stochastic) and uses repeated random sampling (Monte Carlo). This type of model was preferred over a 'simple' cost-benefit analysis, as it better helps to understand

and gain thorough insight into the problem. The basis of the developed model can be classified as a bio-economic model: the different cost factors due to the presence of foot disorders are linked to the presence and severity of the foot disorders. For the welfare assessment this model was adjusted; instead of the economic cost factors the impact on welfare was related to the presence of the foot disorders. Two categories of bio-economic models can be distinguished: simulation and optimization (Prellezo et al., 2012). Based on the objective to gain more insight into the economic consequences and welfare impact of foot disorders (chapter 2 and 3), and effects of intervention measures to improve foot health in dairy cattle (chapter 4), a 'what if' type of model (i.e. simulation), was most suitable.

Model input and gaps in knowledge

A point of concern when using a modeling approach is the quality of the input, which determines the quality of the output. The information used, has been based primarily on the currently available scientific literature, supplemented by expertise from experts in the field of dairy farming and dairy cow foot health and non-scientific literature. During the process of modeling, gaps in knowledge were revealed. It became clear that, despite the amount of research and increased attention in animal and veterinary science for foot disorders in dairy cattle, a lot of specific information is still missing, inaccurate or inconsistent. The basis of the simulation model, used for each of the three model studies, deals with the occurrence of foot disorders. It was challenging to determine the duration of the different foot disorders, especially for the subclinical stage (where the cows are not clearly visibly lame). Based on the data by Somers (2004), prevalence of clinical and subclinical foot disorders on different moments gave a starting point to extrapolate to incidences by using other literature on specific foot disorder epidemiology (e.g., Manske et al., 2002; Holzhauer et al., 2006b). Another important finding was the lack of consistency between scientists about pathology, nomenclature and development of the different foot disorders. Previously, Holzhauer et al. (2006a) already showed the inconsistency in diagnosing foot disorders by foot trimmers and farmers in a farm study. Inconsistency in diagnosing and studying foot disorders is a striking and important observation as it influences the interpretation and direction for further studies and approaches for improvement.

Next to the inconsistency in diagnosis of foot disorders, a diversity in interpretation has also been observed for the assessment of pain impact of foot disorders, used for the modeling of welfare impact (chapter 3). The experts in the panel varied in their assessment of pain impact of the different foot disorders and the weighing of severity against duration. However, the use of experts is valuable when there is not enough information available. Therefore, to estimate the pain impact of different foot disorders, both literature and expertise have been used. The estimations made based on literature did not differ significantly from the averages of the expert estimations. The results from the expert panel did not change the estimation based on literature, however, they confirmed the estimation and showed the diversity in estimations, which gave a nice illustration of the variety in interpretations. Furthermore, the scientific literature about the effects of intervention measures for improvement of dairy cow foot health also showed knowledge gaps and inconsistencies. However, the experience that experts did not change the final estimation, but mainly gave a range around the found mean, indicated it was not necessary to consult experts about the intervention measures. A method, for example, used by Huijps et al. (2010b) to estimate efficacy of intervention measures to control mastitis. In the following sections, for all of the three model parts some of the gaps in knowledge will be discussed.

Assessing economic consequences. In chapter 2 the economic consequences of the different foot disorders have been assessed. In order to assess these economic consequences the effects of different cost factors have been estimated. For these estimations it was for example difficult to determine how much milk production losses are caused by the different foot disorders. Different studies gave different numbers, the inconsistency is for example shown with the production losses for digital dermatitis and claw horn lesions (Warnick et al., 2001; Hernandez et al., 2002; Amory et al., 2008). Furthermore, specific data on infertility or culling due to specific foot disorders was not available. Only studies looking at fertility problems or culling in relation to lameness or locomotion scores were available (e.g., Whitaker et al., 2004; Bicalho et al., 2007). This means that the used probabilities for culling and prolonged calving interval were kept equal for the various foot disorders.

Assessing welfare impact. For the estimation of welfare impact the gaps in knowledge made the assessment even more challenging than for the economic assessment because of the weighing component in the welfare assessment. In chapter 3 it is explained that for an ideal assessment of welfare impact the different aspects of animal welfare, functioning, feeling and natural living (Fraser et al., 1997), are included. The different aspects of welfare needed to be weighed against each other. This is rather difficult without complete information to base the weighing on. Different effects of foot disorders on dairy cow welfare have been studied, such as the effect on lying behavior (Chapinal et al., 2010; Blackie et al., 2011), visits to feeder or automatic milking system, both indicating the walking behavior, (Bach et al., 2007; Borderas et al., 2008), or social behavior (Galindo and Broom, 2002; Walker et al., 2008). However, it is practically impossible to determine the importance, or weigh these effects against each other, because the importance of the affected behaviors and fulfillment of needs is hard to determine as well as the relation with different levels of pain. The incomplete information of different behaviors led to the decision to use pain and the effect on locomotion as indicator for welfare impact, because it was assumed to directly affect dairy cow welfare (Flower and Weary, 2009). Another weighing aspect was the question about what is worse: short and severe pain or longer but less intense pain? There is no consensus about this, as also the answers by the expert panel showed. This is due to gaps in knowledge about the effects on behavior and fulfillment of needs, and the weighing thereof. An interesting aspect in this weighing, that has not been mentioned yet, is the role of sensitization (becoming sensitive or hypersensitive) to pain. Whay et al. (1998) showed that hyperalgesia occurs due to foot disorders. This can affect the weighing factor of duration to a certain extent, as being more sensitive to pain during presence of foot disorders could increase the weight of duration. As a consequence the impact of, for instance IDHE, a foot disorder being present subclinically for long periods of time can then increase. Moreover, trying to decide how to model and weigh different aspects, the question arose what to do with the premature culling of dairy cows due to foot disorders. The presence of foot disorders, especially the severe and recurrent ones, lead to the question whether to treat or cull a cow. The issue about longevity and animal welfare was discussed further in chapter 5.

Assessing effects of intervention measures. Chapter 4 described the costs and benefits of intervention measures aimed at improvement of dairy cow foot health, both for the economic consequences and welfare impact. Although the measures modeled were limited to measures which were applicable on a common Dutch dairy farm with cubicle housing, still many assumptions needed to be made to model these interventions. For example, the amount of bedding to improve lying places, or the costs and benefits of reducing stocking density to 95%. Besides the difficulties with the assumptions on the measures, the assessment of the effect of the measures was difficult due to lacking and/or inconsistent findings in literature. However, the assumptions and estimations of costs and effects are based on the available knowledge, where the assumptions have been explained. The results, at least, give an idea about relative effectiveness of measures and the gaps in knowledge. Another gap in knowledge concerns the combined effect of taking multiple measures. It would be valuable to know more about the possible added effect of taking a combination of measures.

Impact of foot disorders on dairy farmer and cow

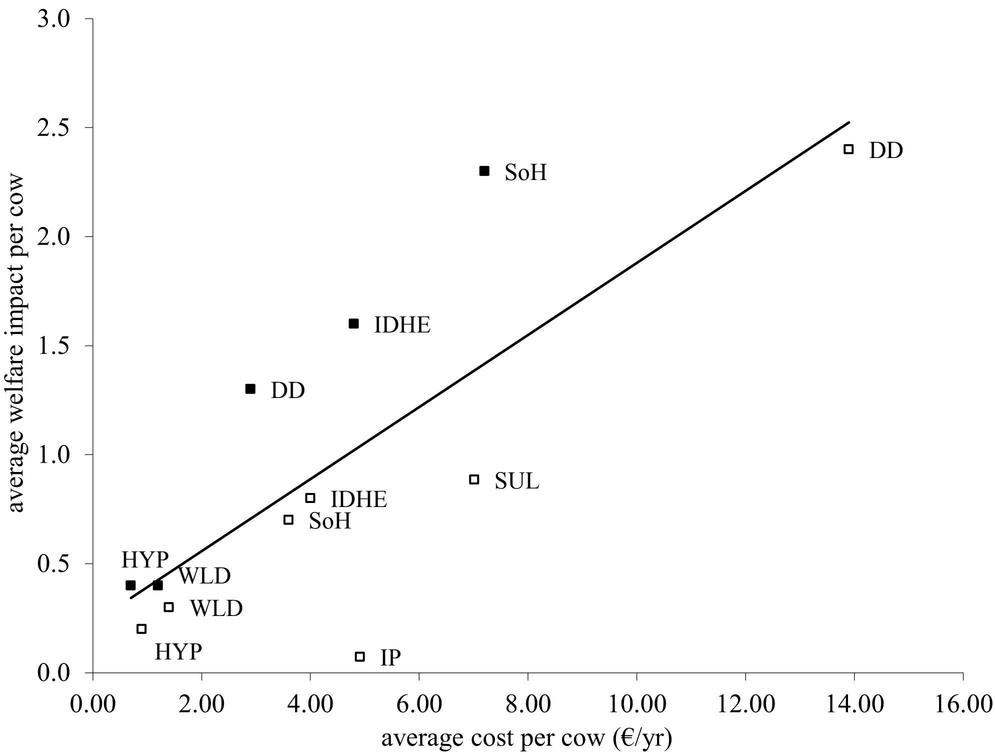
Despite the mentioned uncertainties in input data and revealing gaps in knowledge, the modeling delivered valuable results. Assessing the economic consequences of foot disorders is a valuable instrument to gain more insight in the effect of foot disorders, as has been done by others (e.g., Enting et al., 1997; Kossaibati and Esslemont, 1997). As indicated in chapter 3, these studies needed an update because farming, foot health status and market situations have been changed. Lately, some more studies on economic effects have been published (e.g., Cha et al., 2010; Ettema et al., 2010). The results in chapter 3 differ from those studies. One explanation for this can be found in the different methods used, for example, Cha et al. (2010) used the optimization technique of dynamic programming. A more important explanation can be found in the assumptions made. These assumptions differ between countries and the interpretation of different literature sources. Moreover, the focus of these studies was only on the lame cases of foot disorders, while in this thesis the different foot disorders in clinical and subclinical stage have been distinguished. Although these studies only included the lame cases, they already indicated that lameness has considerable economic impact. Besides the considerable impact of foot disorders, this thesis also provided insight in how the costs are divided over different cost factors. A better idea of where most of the losses go to, can help to increase the awareness, as you will only see the losses if you know they occur and can be prevented. The economic impact due to foot disorders is to a large extent caused by the non-visible costs, like milk production, fertility problems and premature culling. The costs directly felt by the farmer, and also mentioned regularly, are costs for the veterinarian and foot trimmer. These costs, however, turn out to be less important. Information about this aspect might also change the idea about consulting such specialists.

In this thesis, the considerable impact of foot disorders has been emphasized. By including the impact on dairy cow welfare and the impact of subclinical foot disorders the problem of foot disorders has been pointed out. The impact on animal welfare shows that the problem is not only serious for the farmer, but also for the cow. Figure 1 shows the association between the economic and welfare impact (Bruijnis et al., 2012). Such information shows that actions to improve welfare can be beneficial for economic returns as well. Investment in time and money still might make it less attractive for farmers to invest (chapter 4), but at least it helps to show that money and welfare are associated and not necessarily counteract with each other. As lame cows are already hardly recognized, probably partly because farmers are used to having lame or unsound walking cows, it is an important finding that subclinical foot disorders have a considerable impact. The subclinical foot disorders are probably recognized even less than the already poorly recognized lame cases.

Welfare can be improved by two means: good prevention or good curative handling by good monitoring and quick and adequate treatment. Paying more attention to prevention of foot disorders is important because it will help to prevent the cows from suffering foot disorders which are not noticed (the subclinical ones). Being more alert and adequate treatment after diagnosis will not prevent the subclinical or less visible lame cases. Furthermore, these cases already have caused much discomfort before the foot disorders become clinical and are noticed by the farmer. Preventing from getting foot disorders is very important from that viewpoint. Therefore, insight into the effect of subclinically present foot disorders might encourage to put more effort in prevention. However, the importance of good diagnosing and adequate treatment should not be forgotten when more preventive measures are taken.

Actions to improve dairy cow foot health

Effect of intervention measures. Only a few of the modeled measures turned out to be interesting for the farmer in terms of cost-effectiveness. The measures estimated to have higher benefits than costs, included improved bedding or mattresses in the cubicles and additional foot trimming (at drying off). Almost 19% (relatively much) of the respondents believed that improved foot trimming could be cost-effective as well. Reducing the stocking density with 5% was estimated to be break even. This corresponds to a study where inefficiency in terms of labor and stocking density at farms with good foot health (<10% lameness prevalence) were outweighed by the gain in milk yield (Barnes et al., 2011).



IP = interdigital phlegmon, IDHE = interdigital dermatitis and heel erosion, DD = digital dermatitis, SoH = sole hemorrhage, WLD = white line disease, SUL = sole ulcer, HYP = interdigital hyperplasia.

Figure 1. Figure presented in Bruijnis et al. (2012). The relation between average costs and the welfare impact per cow in the herd over one year by clinical state (= □) and subclinical state (= ■). The Spearman rank correlation is 0.64 (p-value < 0.05).

Half of the respondents (chapter 6) believed that reducing stocking density and improving the lying places improve the welfare of the cows. This believed improvement of welfare was not necessarily related to improved foot health, as only a quarter of the respondents thought to improve foot health with these measures. These results may imply that farmers think that the measures will improve other health issues, or it is likely that farmers are aware that improvement of welfare is more than health. The aspect of comfort for the cow, i.e. being able to move and lie down without problems (which more relates to the feeling and natural living aspects of animal welfare), seems to be signaled by these results. However, the effect on comfort did not lead to an intention to apply the measure. More attention to such 'comfort measures' is likely to become more important because there is a tendency not to pasture cows anymore. For such farms the attention for foot health is even more important as pasturing can have a positive effect on foot health (Somers et al., 2003) and can provide a comfortable walking and lying area. The added value of rubber flooring, providing a soft floor with more grip than concrete, could then become more evident.

Most modeled measures were estimated not to be cost-effective which means it will cost the farmer money to implement the measure. However, Barnes et al. (2011) found that a low lameness prevalence (<10%) is positively related with technical results. Achieving better technical results could serve as another incentive, in terms of job satisfaction, next to the economic component. Job satisfaction was valued highly by the respondents but not (yet) related to the intention to take action for improvement of dairy cow foot health.

Other intervention measures. There are more intervention measures to improve foot health on dairy farms with cubicle housing than described in chapter 4. Adjusting the breeding strategy, putting dry cows in a straw yard or improving stockmanship are examples of possible other measures farmers could execute. However, these intervention measures were considered to depend on too many factors and leading to too much variation. Therefore, these measures have been left out of the results section in chapter 4. It would however be valuable to obtain more specific information on these measures, as is also suggested in other studies, e.g., that more foot disorder specific information is needed to improve the selection and breeding on foot health (König et al., 2005). The effect of an adjusted breeding strategy is indicated to have a relatively small effect (personal communication, René van der Linde, CRV), but can give an added effect next to implementation of other measures. Furthermore, many farmers think it is important to include breeding when trying to improve foot health. Breeding was the second most popular measure from the proposed measures in the questionnaire. A reliable estimation of the effects of breeding strategy on foot health can support an informed decision by putting the measure in perspective. Moreover, the questionnaire showed that increasing the frequency to check the cows was the measure which most farmers intended to take. This touches upon improved stockmanship but is rather difficult to model as it is determined by very specific aspects differing between farms and farmers. However, stockmanship is an important aspect, as the stockpersons attitude and knowledge are important for the improvement of dairy cow (foot) health and welfare (Mill and Ward, 1994; Hanna et al., 2009). A measure not very popular among dairy farmers, but very interesting with regard to the ability for the cow to be free from discomfort and being able to perform species-specific behavior (in chapter 3 referred to as cow comfort), would be the housing of dry cows in a straw yard. Estimation of that measure is also very farm specific and depending on many other farm factors and was therefore not suitable to model.

Interventions beyond cubicle housing. The modeled intervention measures were limited to measures which could be executed on a common dairy farm with cubicle housing. In order to improve dairy cow foot health on regular farms in The Netherlands, these insights can help to improve the foot health situation of many cows. Moreover, it is very likely that cubicle housing will be the main housing system coming decades thus directions for improvement in that system are very valuable. However, on the long term and for farmers who look for new opportunities, it might be very valuable to look into possibilities of other housing systems. There are already studies going on about free stalls. For dairy cow health and welfare, new concepts might be preferable, as such systems have soft flooring with grip and very comfortable lying places. Points of attention are, for example, labor efficiency, hygiene and environmental impact, and are subject in studies investigating new concepts for housing of dairy cows (e.g., Galama and Van Dooren, 2008).

Implications based on the modeling outcomes

The used modeling approach was not a farm specific model but gave results for average Dutch circumstances. To raise awareness about the economic and welfare impact of foot this disorders, this type of model was suitable, as it gave insight into the impact of foot disorders and delivered a standard to which future farm specific model assessment can be compared. The results do give directions for further research, which can be used to develop the used models further to farm specific models. Farm specific modeling is a type of modeling needed to support individual farmers in their decisions. As Huijps (2009) states: “Decision support must in all cases be based on farm specific characteristics and not on averages. To really support in on-farm decisions indeed it is important to have farm specific calculations.”

A better understanding of the problem is a good start to improve the foot health situation in dairy farming. The importance to pay attention to this problem is shown clearly and has been emphasized by the considerable impact of subclinical foot disorders which are even more difficult to detect than the underestimated clinical cases. A clear message about considerable impact of foot disorders is important as Leach et al. (2010a) also showed that "many farmers are not aware of the cost of lameness to the farm business and do not realize the full implications of their lameness problem in terms of productivity or profitability". And Leach et al. (2010b) also stated: "Therefore, there is a need to overcome this and increase their awareness of poor welfare among their cows, so that their professed concern for animal welfare results in action to reduce lameness." This thesis contributes to increasing the awareness of farmers about the impact of foot disorders by showing the serious impact, on both economics and welfare, of the different disorders, clinical and subclinical. The attitude of farmers regarding dairy cow foot health and what is reasonable to expect from farmers, will be discussed in a next paragraph.

Due to financial constraints and/or regulatory restrictions (e.g., environmental legislation) farmers are limited in their choice which measures they can take. Information on the effect of intervention measures on economics and animal welfare can support farmers in taking thoughtful decisions. The ranking of the measures in this study and the most likely range of the extent measures will have effects (sensitivity analysis), helps in determining what can be useful options for improvement. But also to determine what are useful research directions, for example, to generate more information to provide more unambiguous advice to dairy farmers. The more precise the estimations for cost-effectiveness, the less ambiguous the advice indeed will be. More unambiguous advise can help to increase the compliance of farmers.

Dairy farmers' attitudes and intentions

The farmers who filled in the questionnaire (chapter 6) seemed to be moderately intended to take action. The study sample was representative for Dutch dairy farming when looking at the characteristics of the farms and farmers. However, the results might be biased, because it is likely that people who have a very good or bad dairy cow foot health status at their farm are more likely to fill in the questionnaire. Furthermore, the farmers who are more active in improving their management and farm practices are more willing to fill in the questionnaire. It is therefore possible that the average intention of the complete population of Dutch dairy farmers is lower compared to the answers of the respondents in this research.

Most farmers seemed not very concerned about the foot health status on their farm. Especially, the presence of subclinical cases was not perceived as a problem or welfare problem by most farmers. This finding is in accordance with other studies where it was found that farmers tend to underestimate the problem of foot disorders (Whay et al., 2002; Leach et al., 2010a; Sarova et al., 2011). The moderate intention to improve the foot health situation is also visible in the low number of measures farmers indicated they intended to take. Different reasons can explain the low intention for taking specific measures. The results from the in-depth interviews confirmed that farmers tend to think about the regularly applied measures when talking about improving dairy cow foot health. These measures include mainly the measures which are applied when there is already a problem, like improving the foot bath management or foot trimming schedule. The measures most likely to be applied were to improve feeding or breeding management. These are easy to apply measures and commonly advised by the feed advisor and foot trimmer. It is a challenge to change the way farmers look at foot health management, as these examples show that farmers have difficulties to change their management. Maybe because of reluctance to change the routine or because giving up what they are doing is more difficult than starting a new measure. Huijps et al. (2010a) showed that with respect to management measures for mastitis control, the farmers expected that a new measure costs more time than the real time needed. For farmers it can have an influence on their job satisfaction to change some management practices to improve dairy cow foot health. For example, putting dry cows in a straw yard will ask more time and other work activities from the farmer. Furthermore, the time of the farmer is scarce. The scarce time has to be divided over various farm activities (e.g., attention for environmental and other health issues) and family activities. The in-depth interviews nicely illustrated that the family situation is a very important aspect for farmers. If everything goes well in the personal situation, then more effort can be put into dairy cow health issues. Furthermore, the money needed to do some investments can have a restrictive effect.

The modeling showed that dairy cow welfare can be improved by certain measures. It might be difficult to persuade farmers to include the cow welfare in their weighing. This might be explained by two reasons. First, because the questionnaire (25% of respondents) and the literature indicate that not all farmers believe that cows can suffer pain (Kielland et al., 2010). Second, the use of analgesics by presence and during treatment of foot disorders is rare (O' Callaghan, 2002). Combining this information with the fact that farmers in the in-depth interviews did not pay much attention to ‘comfort measures’ and species-specific behavior of their cows, but paid more attention to the functional aspects which relate to the production level of the cow, indicates that welfare aspects are not likely to influence dairy farmers’ management decisions. This conflicts with chapter 5 in this thesis where it is argued that the concept of animal welfare is more than the traditional functioning and feeling, but also included the aspect of fulfilling species-specific needs. The single use of the view on functioning and health is likely to result in an underestimation of the benefits of ‘comfort measures’, because the welfare of the cows can improve without improving the foot health directly.

As mentioned earlier, attention for new concepts for housing dairy cows can be important as well with regard to dairy cow foot health and welfare. It will be difficult to convince farmers to be open to new concepts because farmers already seem to have a reluctant attitude towards taking other intervention measures than the most commonly mentioned ones. This lack of compliance was already shown by Bell et al. (2009). Especially nowadays, where there is serious attention for animal welfare, it is valuable to pay attention to the relation of foot disorders and welfare, and how this should be solved optimally. This includes looking further than the clearly visible lame cases and executing the easy and well known measures when there are already problems with foot health (such as foot trimming and foot bathing), without taking into account the effect on comfort and welfare of the cows. One way is to try to convince farmers by proving the positive effects by experimental and practical studies. However, most measures or new concepts will need a substantial investment. As long as farmers are not convinced that new concepts will bring positive effects for them, substantial investments (such as a new barn) will be limited to the known concepts. Cost-effectiveness will not be a persuading argument to consider new concepts, therefore, there is a need to include other aspects than economy (Meijboom et al., 2009). Another approach needs to include the advisors of the farmers, the advice of these actors should be more unambiguous and aimed at improvement of welfare, which goes further than production levels.

Other aspects than economics need to be taken into account and need to be endorsed by the different people who can play a role in improvement of dairy cow foot health. The feed advisor and foot trimmer are indicated to be important advisors for dairy cow foot health. The consistency of their advice is important, but also the content; the advisors need to be critical about the foot health situation. It can be questioned whether the advisors do acknowledge the importance of foot health, and whether their advice is congruent and ambitious enough compared to the prevailing norms about how we should treat animals. A veterinarian is more likely to have an overall view of the farm and has another role than the feed advisor whose primary objective is to sell feed and feed supplements. The advice of veterinarians seems to be taken serious, but not with respect to foot health. That indicates a possible new opportunities for advise and support towards the farmer. Although recent research showed that for farmers who did not want or quit herd health advice from the veterinarian, high costs and low return were the most important reasons not to participate (anymore). Furthermore the same study showed that there was a lack of communication between dairy farmer and veterinarian about the advice on herd health management (Derks et al., 2012). Attention for the quality of communication by veterinarians and the importance of a uniform message has already been pointed out (Lam et al., 2011).

Role of the dairy farmer

This thesis provides insight into different aspects of dairy cow foot health. Besides giving more insight into the current situation of this important welfare problem in dairy farming, it is also shown that the problem of foot disorders in dairy cattle leads to moral dilemmas. An important question regarding dairy cow foot health is what we reasonably can expect from dairy farmers. In order to find new strategies to improve dairy cow foot health, both the facts about the current situation and the moral aspects are important. The facts about the current situation, based on this thesis, will be summarized shortly and will be followed by an exploration of some moral aspects. The importance of this welfare problem will be discussed, followed by an explanation of how the valuing of animals has evolved and has led to the current valuing of animals and animal welfare. Then the context of our dealing with animals and differences in valuing of animals will be discussed as well as the weighing of animal welfare against other relevant issues in dairy farming. Based on these steps the role of dairy farmers with regard to dairy cow foot health improvement will become clear.

Current situation with regard to dairy cow foot health

In ethics it is logical to presume that ought implies can[1]. Therefore, when studying what we can reasonably expect from dairy farmers, it is important to look at what is realistic. Based on this thesis it can be concluded that assessment of the current situation is not that easy. It is shown that the impact of foot disorders is considerable, both in terms of economic consequences for the farmer as for the welfare impact on the cow. The considerable impact of subclinical cases of foot disorders implies that the problem is likely to have more impact than stakeholders are aware of. Furthermore, it showed that measures for improvement will improve foot health status, and with that dairy cow welfare. However, most measures seemed not to be cost-effective. During the assessment it appeared that it is rather difficult to make a reliable estimation of the impact of foot disorders as well as for the consequences of taking action for improvement of dairy cow foot health. Gaps in knowledge about this issue were revealed and directions for new studies have been indicated. The uncertainty about specific estimations is important to keep in mind when, for example, informing farmers and trying to convince farmers to take action(s). Especially, because the calculations about intervention measures did not match with the ideas of most farmers about cost-effectiveness of measures. Most farmers intended to improve dairy cow foot health, however, the intention was moderate and it seemed that there was no real urgency for improvement. Furthermore, the measures other than the routinely and already familiar ones, seemed not to be an option for most farmers.

[1] The ‘ought implies can’ principle is often ascribed to Kant, he refers to it in his ‘Kritik der praktischen Vernunft’. It has been mentioned before by, for example, Thomas Hobbes in his work Leviathan (1651).

Importance of improving dairy cow foot health

Foot disorders in dairy cattle are an important problem in dairy farming. Different stakeholders have noted that the current situation with respect to dairy cow foot health is an undesirable situation. Currently, approximately 30% of all cows with a foot disorder (80% of the cows) in The Netherlands becomes lame in one year (Frankena et al., 2009). Farmer organization LTO aims to achieve a 30% improvement of leg- and claw health by a pilot study where farmers are advised by professionals visiting the farm (veterinarian, feed advisor, foot trimmer). FrieslandCampina, largest dairy organization in The Netherlands, aims to achieve a 'natural level' of lameness among their farms. This level entails an incidence of 10% to be achieved in 2020 (FrieslandCampina, 2011). These two targets differ and both do not mention the targets for the subclinically present foot disorders. However, both state that there is a need to improve dairy cow foot health. This is a starting point to put dairy cow foot health higher on the agenda. A more uniform target, including the less visible or subclinical cases as well, would be a desirable next step. It is difficult to give an unambiguous interpretation, for both the assessment of the current situation as for the morality about the problem of foot disorders. Because of these differences, it is not easy to determine what is reasonable to expect from the farmer. The farmer plays a central role in the analysis about what ought to happen with regard to dairy cow foot health. This central role is based on the fact that the farmer by law is responsible for the health and welfare of his cows. Furthermore, the farmer is the one deciding about the housing of the cows and management on a farm, directly affecting the health and welfare status of the cows. The assumption in this thesis is that the dairy farmer is the one responsible for taking care of the cow and has the duty to provide for a good foot health and welfare of the dairy cow. The question is, what can we reasonably expect?

Value of animals over time

Developments in the valuing of animals can be seen in the evolving literature in animal ethics. Starting with the famous words by the utilitarian Bentham (1789) "The question is not, Can they reason? nor, Can they talk? But, Can they suffer?". Nonetheless, it was only in the 20^{th} century that the debate about the moral status of animals started. Based on Bentham, the utilitarian Singer (1993) argues that animals have interests, based on the argument that animals have sentience, and the assumption that sentience implies the capacity to suffer and having interests. He proposes that suffering for humans and sentient animals is morally seen equal, although the causes for suffering can be due to different reasons, because species have specific interests. To illustrate, both humans and cows need drinking water of good quality, however, a cow will have other needs in terms of quality requirements and amounts than humans do. However, when a cow is suffering with a same duration and intensity as a human because of insufficient quality and provision of water, according to Singer, the moral importance is equal. Another way that can explain why we see foot disorders as a problem is a deontological approach, as used by Regan (1983). A deontological approach does have the act itself as a central point rather than the goal or end product, like preference-satisfaction or maximizing utility for Singer. In this approach the individual is important and it is a prima facie duty not to harm a so-called being that is subject-of-a-life. Being a subject-of-a-life means having cognitive capacities that are necessary for beliefs, desires and having a sense of time. Regan's reasoning to grant inherent value results in a plea for animal rights. These rights do not entail that animals have the same interests as humans, but that the interests of animals should be taken as seriously as human interests and should also be protected by rights.

These examples from the literature show there is a development in morality about our dealing with animals. As already mentioned in this thesis, the considerations about how to treat animals are fueled by and go together with the development in knowledge of animal biology (physiology, ethology, neuroscience, etc.). The acquired knowledge has led to new insights into what is important for animal welfare, leading to new ethical issues. An example of such an issue is whether longevity should be considered as an animal welfare issue (chapter 5). The welfare assessment in chapter 3 gave rise to this question. The presence of a foot disorder affects the welfare of the cow, and especially the severe and recurrent foot disorders, lead to the decision to cull cows prematurely. In general, it is agreed upon that the killing of a cow can then indicate that welfare is affected. However, there is less consensus about whether the premature culling, which affects the longevity, affects animal welfare. It is often reasoned that culling will prevent the animal from suffering, especially when recovery is not likely and can be a long and painful process for the cow (especially because the use of analgesics is not common). However, in the assessment of welfare it felt counterintuitive not to acknowledge the importance of longevity for the welfare impact of premature culling. This led to the analysis in chapter 5, which illustrated the moral relevance of this important welfare problem in dairy farming. The increased demand for animal welfare has also been identified by the Dutch Council for Animal Affairs (RDA, 2010). Based on the changing values it can be concluded that welfare problems in animal farming result in moral duties to do something to improve animal welfare.

To secure a certain minimum level of animal welfare, legislation has evolved over the years. This development is to a large extent caused by demands from society and societal organizations. Nowadays, the intrinsic value of animals is commonly acknowledged and grounded in Dutch law. In The Netherlands the Animal Health and Welfare Act will change to Act Animals in January 2013. An important starting point in this Act is that the intrinsic value of the animal is taken as base and with that health and welfare should be secured. However, the Act does not give concrete rules to secure animal welfare, or foot health of dairy cattle. Instead, it uses amongst others the aspects mentioned in the widely known five freedoms (e.g., FAWC) to define guidelines to provide for a good health and welfare of the animals and respect the intrinsic value of animals. This means that the duty of dairy farmers to provide for a good health and welfare of their cattle is guaranteed by law. However, the law does give some room for different interpretations about what is good health and welfare and how to provide for this.

Changing context and differing values

The ideas about to what extent dairy farmers have to take action to improve dairy cow foot health, and with that dairy cow welfare, depends on the context and on the values one holds. The developments in our valuing of animals is, next to the influence of knowledge and morality, fueled by a shift in the way people deal with animals. Over time, fewer people are involved in agriculture and animal husbandry. Nowadays, only about 3% of the working population is active in the agricultural sector, while in the 1950's 20% of the working population worked in the agricultural sector (CBS StatLine; LEI). This means that most people nowadays have no direct relation with animals used for food production. Big contrasts have been identified in how people value animals, which depends on the context and the relation people have with animals (RDA, 2010; Meijboom, 2012). The changed relationship is nicely illustrated by an empirical ethical study by Cohen et al. (2007), as also cited in chapter 5: "The relationship between man and animal has in recent years evolved from a purely functional relationship in which the animal is valued mostly for its instrumental utility to humans, towards one in which respect for the value of the animal as a being in its own right plays a significant role.". The functional role is based on the use of animals used for production, which has become more businesslike (RDA, 2010), the other role has come up by using animals for other purposes than production of food, like the back yard animals and pet animals. The relation of a dairy farmer with its animals is based on the goal to produce food, this results in another role than being a companion or subject of hobby for the backyard animal keeper (Holloway, 2001), or the role of family member for many pets in modern households. The context, which determines the relation with and knowledge about animals, influences the values a person holds towards animals. To illustrate, a dairy farmer and a back yard animal keeper both can say that they value animal welfare as important. However, they can have a different interpretation of what good welfare is. For example, dairy farmers work with cows to earn an income, where freedom from diseases and good production are important aspects. For a backyard cow keeper other aspects are more important, for example, the exterior for a breeding animal or the sociability of the companion. In both situations, the valuation concerns cow welfare, however, due to the different context the valuation leads to different decisions with respect to the health and welfare of the animals (Holloway, 2001). Having a foot disorder is for a dairy farmer problematic, mainly because of production loss, labor, etc., while for a back yard cow keeper the disorder will have less importance in terms of economics, but more because of affecting the animal in its naturalness, its beauty as breeding animal or being the animal in the role of companion.

When considering the dairy cow, there is also a conflict between how farmers value and interpret animal welfare and how society values and interprets animal welfare. Many people in society believe that a natural surrounding and naturalness are very important for animal welfare, while farmers focus more on functioning and health (Te Velde et al., 2002; De Greef et al., 2006; Vanhonacker et al., 2008). This will lead, enforced by the different relation a farmer or citizen has with the cows, to another interpretation of how important the welfare problem of foot disorders is. The opinion of society about the treatment of production animals should be taken serious, however, their opinion should be put in perspective. It is important to keep in mind that many people have no close connection to animal production and have a restricted knowledge about animals and their species-specific needs. Moreover, people tend to be ambiguous when talking about the welfare of farm animals compared to the way they treat their own animals; the needs and naturalness of many pet animals are not acknowledged as well (cf. for example a dog in a handbag used more as accessory than as a being).

Weighing values

When a farmer acknowledges the intrinsic value of the animal and the duty to provide good health and welfare, still the welfare has to be weighed against other relevant issues in the context of dairy farming. The context influences to what extent a farmer can provide for a good animal welfare (cf. Cohen et al., 2009). Other issues that influence the weighing and decision making of farmers are, for example, economic aspects, food safety and personal preferences. Managing a dairy farm entails taking decisions on many different aspects like labor, dairy cow health control, environmental issues, short and long term investments, etc., which leads to the necessity to prioritize when making decisions. Therefore, foot disorder management needs to be weighed against these other issues. An example of another important health issue is mastitis, a very costly production disease for the farmer which on average costs €78 per cow per year (Huijps et al., 2008). Mastitis has a direct influence on food safety and food quality. A primary aim of dairy farming is the production of safe and good quality milk, therefore, the importance of this disease is weighed heavily. To assure quality, a penalty system has also been introduced to control mastitis. In recent years there has been much attention for udder health, which can be seen in, for example the establishment of the Dutch Centre for Udder Health and the amount of research in that field.

Farmers need to weigh their farming decisions and choose which actions to take based on their morality and their economical and practical abilities. In our society professional autonomy is generally respected. For farmers this entails, for example, to take decisions to run a profitable farm, have good working conditions and to manage a herd of healthy cows. Research has also shown that people in society find it important that farmers can run a profitable farm in good circumstances (Rutgers et al., 2003; Boogaard et al., 2008). Despite the respect for the farmer, people might not always be aware of the impossibilities to meet expectations from society, due to the demands on, for example, labor efforts and financial investments. For example, most people in society like to see a cow in pasture, but the possibilities for individual farmers might be limited to meet this request from society. Furthermore, it should be noted that pasturing can be good for the welfare of the cows when applied in a proper way (i.e. good pasture, shelter for heat, good path, etc.). However, when the housing, the place where the animals are most of the time, is not appropriate to fulfill the needs of the cows, welfare is still not assured.

What to expect from dairy farmers to improve dairy cow foot health?

Based on the developments in our thinking about animals it can be presumed that animals deserve moral consideration as beings with an intrinsic value. This implies that the interests of animals should be taken seriously. These interests include a good health and welfare. Given the considerable impact on dairy cow health and welfare, and the notion by different stakeholders that the current foot health status is not satisfactory, more effort to improve the situation is needed.

Accepting the current status of foot health with a high prevalence of foot disorders, would result in a situation where farmers do not fulfill their duty to provide for a good welfare of their cows. The awareness of farmers about this problem needs to be raised, as well as the importance of this problem compared to other issues in dairy farming and in terms of welfare. A broader concept of animal welfare needs to be accepted and implemented to achieve real improvements.

Conclusions and recommendations

Based on this thesis it can be concluded that the impact of foot disorders is considerable, both in terms of economic consequences for the farmer as for the welfare impact on the cow. The considerable impact of subclinical cases of foot disorders implies that the problem is likely to have more impact than stakeholders are aware of. Taking intervention measures will improve foot health status to a certain extent. Improving the lying surface, additional foot trimming and reducing the stocking density were assessed to be cost-effective or break even. However, most measures seemed not to be cost-effective. Gaps in knowledge made it rather difficult to make an estimation of the impact of foot disorders as well as for the consequences of taking action for improvement of dairy cow foot health, indicating directions for new studies. Most farmers intended to improve dairy cow foot health, however, the intention was moderate. Most important driver seemed to be the achievement of better foot health with cost-effective measures. The measures other than the routinely and already familiar ones, seemed not to be an option for most farmers. The thesis finishes with the question: what can we reasonably expect from dairy farmers with regard to improving dairy cow foot health? Based on developments in our valuing of and dealing with animals, it can be concluded that the current situation of dairy cow foot health is not acceptable. The farmer is the one responsible for providing good health and welfare of his dairy cows. This thesis shows that the interpretation of animal welfare by farmers is different from a broader concept of animal welfare, proposed in this thesis, but also differs from the concept people in society hold. Subclinical foot disorders (not visibly lame) were not valued as important with respect to animal welfare. Furthermore, 25% of the respondents did not believe cows could suffer pain.

Farmers need to weigh the importance of improving foot health, and animal welfare, against other issues at the farm. In order to achieve improvements in dairy farming, the whole sector needs to acknowledge animal welfare as a concept that entails more than health and functioning. This will lead to an increased importance of improving dairy cow foot health, making it more a priority to take concerted action.

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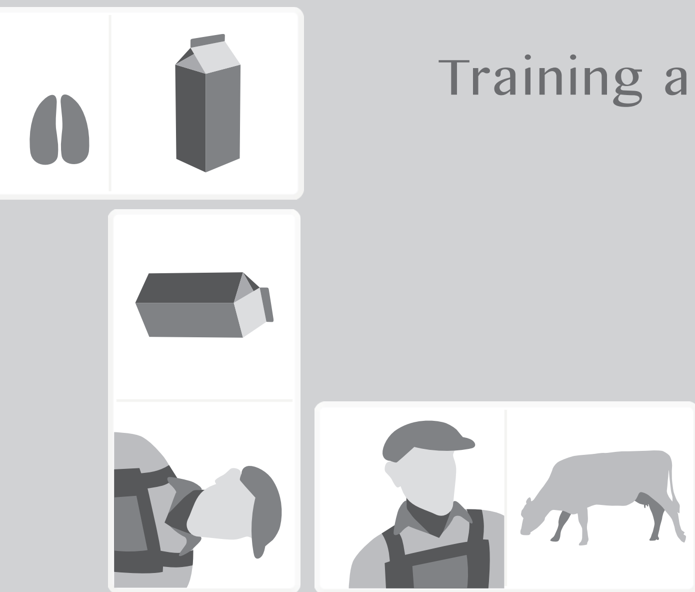
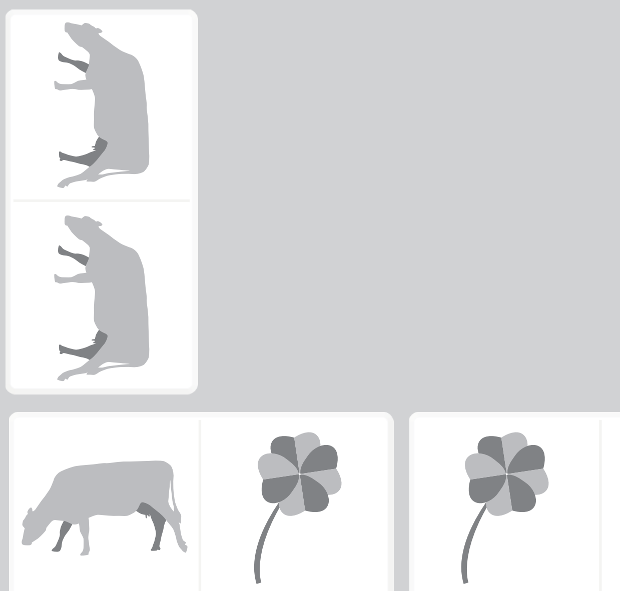
Chapter 8





Summary

Foot disorders and the resulting lameness are an important problem in modern dairy farming. Based on the incidence, duration and severity, foot disorders are considered the most important welfare problem. Despite much knowledge about foot disorders and their risk factors, a reduction in the prevalence of foot disorders and lameness has not been achieved. Besides, dairy farmers underestimate the problem of foot disorders as well as the relation with lameness.

To improve dairy cattle welfare, it is important to increase the awareness of stakeholders. The aim of this thesis is to increase the awareness about the problem of foot disorders in dairy farming. A socio-economic approach is used to gain insight into this welfare problem and find strategies to improve dairy cow foot health. The thesis consists of two parts. One part, based on modeling, aims to gain more insight into the consequences of different foot disorders and the intervention measures to improve dairy cow foot health. Both the clinical foot disorders (cow is visibly lame) and subclinical foot disorders (cow is not visibly lame, visible by inspection of the feet) were included. The model studies aim at both consequences for the farmer, in terms of economic consequences, and consequences for the dairy cow, in terms of animal welfare. The other part deals with the social and moral aspects. This part includes a discussion about the concept of animal welfare, where the question is considered whether longevity is an issue of animal welfare. This is followed by a study into the attitude of dairy farmers with respect to dairy cow foot health and the intention to take action for its improvement. The thesis finishes with an analysis of the role of the dairy farmer with respect to the problem of foot disorders.

The first part of the thesis used a modeling approach. A dynamic stochastic simulation model has been developed. The basis of this model was to simulate the occurrence of the foot disorders, using scientific literature and available knowledge to build the model. Based on literature the seven most important foot disorders were distinguished. The first step to raise awareness was a study aimed at gaining insight into the impact of foot disorders for the farmer. This led to the following objective for chapter 2: estimate the economic consequences of different types of foot disorders, both clinical and subclinical. The economic consequences which occur due to presence of the different foot disorders were modeled, using the bio-economic simulation model. The following cost factors were distinguished: costs due to milk production losses, premature culling, prolonged calving interval, labor of the dairy farmer, costs for the foot trimmer, visits of a veterinarian, treatment costs (e.g., antibiotics), and discarded milk. The default calculation assumed a common Dutch farm (cubicle housing, concrete (slatted) flooring, pasturing during summer months and two foot trimming interventions per year) with 65 cows in a milk quota system. For this default farm the costs averaged €3,474 per year, varying from €2,282 to €4,965; an annual loss of €53 per average cow in the herd. The costs of subclinical foot disorders make up 32% of all costs due to foot disorders. The costs due to foot disorders that are present

without treatment or detection by the farmer are therefore considerable. This finding implies that farmers might underestimate the benefits of taking action earlier and more thoroughly. The highest costs, classified by foot disorder, were those due to digital dermatitis, which has a high incidence and relatively high clinical prevalence. The highest costs, classified by cost factor, were those due to milk production losses and culling. Sensitivity analysis showed that variables regarding milk production were important for the economic costs due to foot disorders. Furthermore, the probabilities of getting a foot disorder and probabilities of cure were important for estimating the costs due to foot disorders. This study showed the considerable impact of foot disorders for the dairy farmer.

The second step to raise awareness was to provide insight into the impact on the cow. In chapter 3 the objective therefore was to assess the welfare impact of the seven foot disorders distinguished. The impact of the specific foot disorders on welfare was assessed by including the incidence, duration and severity of the foot disorders. The pain scores for each foot disorder in clinical and subclinical stage were estimated and used in the simulation model. This pain score was based on locomotion and pathophysiology of the foot disorders, using scientific literature and expert opinions. Animal welfare assessment ideally includes the different aspects of animal welfare; functioning and health, feeling, and natural living. To model these different aspects, too few information was available. The pain was used as an indicator as it was assumed to reflect the impact on all three aspects of animal welfare. The negative welfare impact was measured on a scale from 0 through 60, where the maximum outcome represents a cow having very severe pain during the whole year. On average each cow in the herd obtains a negative welfare impact score of 12 which is 20% of the maximum welfare impact score. This welfare score equals having severe pain for a period of three months, indicating a serious impact on welfare. On average, digital dermatitis (DD) impacts most on welfare, which is caused by a high incidence of the painful clinical stage, followed by sole hemorrhages (SoH) and interdigital dermatitis and heel horn erosion (IDHE). The combination of a high incidence and long duration of SoH and IDHE cause this relative high welfare impact of foot disorders that occur mostly subclinical. On average, over one year, 46% of the welfare impact due to foot disorders is caused by clinical foot disorders. The fact that subclinical foot disorders contribute more or less equally to the effects on welfare as clinical ones, indicated that farmers probably underestimate the welfare impact reasonably. The individual cases of foot disorders, representing welfare impact at cow level, stress the importance of pain intensity, indicating the importance of clinical foot disorders. Furthermore, the approach of welfare assessment, for example herd versus cow level, influenced the ranking of foot disorders for their impact on animal welfare. Potentially, this leads to different prioritization of specific solution strategies for dairy farmers, e.g., focusing on cow comfort, hygiene or preventive medical treatments, foot trimming and / or health monitoring or specific curative treatments. The results for both the economic consequences and animal welfare impact demonstrate the seriousness of the problem of foot disorders in dairy cattle.

After having obtained insight into the impact of foot disorders, the effects of intervention measures to improve dairy cow foot health have been assessed. The objective of chapter 4 was to assess the costs and benefits of different intervention measures to improve dairy cow foot health, both for economics and welfare. Intervention measures were modeled when they were applicable on a dairy farm with cubicle housing and when sufficient information was available in literature. Net costs were calculated as the difference between the costs of the measure and the economic benefits resulting from the measure. Welfare benefits were calculated by comparing the negative welfare impact of the default situation with the estimated impact after implementing the measure. The model outcomes indicated that improving lying surface (mattress and bedding) and performing additional foot trimming were cost-effective measures. Reducing stocking density was assessed to be break even. The improved lying surface and reduced stocking density also have a relative high welfare benefit. More insight into cost-effectiveness and welfare benefits of intervention measures can help to prioritize when choosing between intervention measures.

After the modeling studies in the first part, which provided insight into the current situation regarding dairy cow foot health, the second part dealt with the social and moral aspects. During the process of modeling the welfare impact of foot disorders on dairy cattle the question arose whether the premature culling due to foot disorders affects animal welfare. The presence of a foot disorders affects the welfare of the cow. Especially the severe and recurrent foot disorders most likely lead to a decision to cull the cow prematurely, and affect the longevity of a cow. In chapter 5 it is explored whether longevity is both a morally relevant aspect in the discussion on killing animals and a constitutive element of animal welfare, rather than a mere indicator of animal welfare. Two steps were taken to explore this. The first step entails a shift from welfare as a concept based mainly on biological knowledge to the notion that animal welfare is based on and informed by biological knowledge but is equally driven by moral norms. The second step entails a shift from views on animal welfare in terms of functioning or feeling well to a view on animal welfare that includes the aspect of natural living in which species-specific preferences and species-specific development are important. Using both normative and biologically based arguments, it is argued that animal welfare should be approached more integrally and that it should be assessed over time. This interpretation is independent of the capacity to comprehend life or have a future orientation. In the practice of dairy farming the inclusion of longevity in welfare assessment implies that premature culling, i.e. cull the animal before the end of the intended productive life, is not a neutral act but one that can affect animal welfare because of its implications for the longevity of a cow. This broadens the scope of evaluating foot disorders. Rather than merely focusing on whether a foot disorder is evaluated in terms of the cow's ability to function in a certain system, this view requires an assessment in which all the interests of an animal, including those related to lifespan, are taken seriously.

When aiming at improvement of dairy cow foot health it is important to take into account the attitude and intention of dairy farmers with regard to this subject. The objective of chapter 6 was to gain insight into the attitude of dairy farmers regarding dairy cow foot health and their intention to take action to improve dairy cow foot health. The Theory of Planned Behavior (TPB) was used to determine drivers and barriers to take action. Furthermore, the framework of the TPB was extended by questions concerning personal normative beliefs, which tell more about farmers' personal values regarding animal welfare and moral obligations towards animals. With information from such a framework, solution strategies for the improvement of dairy cow foot health can be proposed. Five hundred dairy farmers were selected randomly and were invited by email to fill in an online questionnaire. The questionnaire included questions about respondents' intentions, attitudes, subjective norms, perceived behavioral control and questions about personal normative beliefs. The results (response rate 30%), showed that almost 70% of the dairy farmers had an intention to take action to improve dairy cow foot health. However, most farmers seemed to be satisfied with the foot health status at their farm, which probably weakened the strength of the intention to improve dairy cow foot health. Most important driver seemed to be the achievement of better foot health with cost-effective measures. Possible barriers to taking action were labor efficiency and the effect of achieving an improved dairy cow foot health a long time after taking action. The feed advisor and foot trimmer seemed to have most influence on intentions to take action to improve dairy cow foot health. Subclinical foot disorders (not visibly lame) were not valued as important with respect to animal welfare. Furthermore, 25% of the respondents did not believe cows could suffer pain. The view on welfare was mainly based on the restricted view on health and functioning. Most farmers did indicate that good care for the cows is important, but that was not associated with the intention to improve dairy cow foot health. The cost-effectiveness of measures seemed to be more important for the intention to take action for dairy cow foot health improvement. Providing more information on the effects of taking intervention measures might stimulate farmers to take action to achieve improvement in dairy cow foot health.

Chapter 7 discusses the methods and outcomes of the preceding chapters, followed by a discussion on the role of the dairy farmer. Based on this thesis it can be concluded that the impact of foot disorders is considerable, both in terms of economic consequences for the farmer as for the welfare impact on the cow. The considerable impact of subclinical cases of foot disorders implies that the problem is likely to have more impact than stakeholders are aware of. Furthermore, it showed that measures for improvement will improve foot health status to a certain extent. However, most measures seemed not to be cost-effective. During the assessments it appeared that it is rather difficult to make an estimation of the impact of foot disorders as well as for the consequences of taking action for improvement of dairy cow foot health. Gaps in knowledge about this issue were revealed and directions for new studies have been indicated. Most farmers intended to improve dairy cow foot health, however, the intention was moderate. Furthermore, the measures other than the routinely and already familiar ones, seemed not to be an option for most farmers. The thesis finishes with the question: what can we reasonably expect from dairy farmers with regard to improving dairy cow foot health? Based on developments in our valuing of and dealing with animals, it can be concluded that the current situation of dairy cow foot health is not acceptable. The farmer is the one responsible for providing good health and welfare of his dairy cows. However, the interpretation of animal welfare by farmers is different from the broader concept of animal welfare, proposed in this thesis, but also differs from the concept people hold in society. Furthermore, a farmer needs to weigh the importance of improving foot health, and animal welfare, against other issues at the farm. In order to achieve improvements in dairy farming, the whole sector needs to acknowledge animal welfare as a concept that entails more than health and functioning. This will lead to an increased importance of improving dairy cow foot health, making it more a priority to take concerted action.

Samenvatting

Klauwaandoeningen en de kreupelheid die daardoor ontstaat zijn een belangrijk probleem in de huidige melkveehouderij. Op basis van de incidentie, duur en ernst van klauwaandoeningen, worden ze aangemerkt als het belangrijkste welzijnsprobleem. Ondanks dat er veel kennis is over de klauwaandoeningen en de risicofactoren, is het probleem nog niet afgenomen. Bovendien onderschatten melkveehouders de grootte van het probleem van klauwaandoeningen, evenals de relatie met kreupelheid.

Om het welzijn van melkvee te verbeteren is het belangrijk om het bewustzijn van het probleem bij de betrokkenen te vergroten. Het doel van dit proefschrift is daarom ook om het bewustzijn over het probleem van klauwaandoeningen in de melkveehouderij te vergroten. Een socio-economische benadering is gebruikt om inzicht te krijgen in dit welzijnsprobleem en om een nieuwe benadering te vinden om klauwgezondheid van melkvee te verbeteren. Dit proefschrift bestaat uit twee onderdelen. Eén onderdeel, dat is gebaseerd op modelleren, heeft tot doel om meer inzicht te krijgen in de gevolgen van verschillende klauwaandoeningen en de effecten van maatregelen om klauwgezondheid te verbeteren. Zowel de klinische klauwaandoeningen (de koe is zichtbaar kreupel) als de subklinische klauwaandoeningen (de koe is niet zichtbaar kreupel, zichtbaar bij inspectie van de klauwen) zijn opgenomen. De modelstudies richten zich enerzijds op de gevolgen voor de melkveehouder, in de vorm van economische gevolgen, anderzijds op de gevolgen voor de melkkoe, in de vorm van impact op het welzijn van de koe. Het andere onderdeel behandelt de sociale en morele aspecten. Dit onderdeel bevat een discussie over het concept welzijn. In dit onderdeel wordt de vraag, of levensduur een dierenwelzijnsissue is, beschouwd. Dit wordt gevolgd door een studie naar de houding van melkveehouders met betrekking tot klauwgezondheid van melkvee en de intentie om actie te nemen voor verbetering daarvan. Dit proefschrift eindigt met een analyse over de rol van de melkveehouder met betrekking tot het probleem van klauwgezondheid in de melkveehouderij.

Het eerste onderdeel van dit proefschrift maakte gebruik van een aanpak met modelstudies. Voor dit doel is een dynamisch, stochastisch simulatie model ontwikkeld. De basis van dit model is het simuleren van de aanwezigheid van de klauwaandoeningen. Om het model te bouwen is gebruik gemaakt van wetenschappelijke literatuur en aanvullende beschikbare kennis. Gebaseerd op de literatuur zijn de zeven belangrijkste klauwaandoeningen onderscheiden. De eerste stap om het bewustzijn te vergroten was een studie om de impact van klauwaandoeningen op de melkveehouder in te schatten. Dit leidde tot de volgende doelstelling voor hoofdstuk 2: het schatten van de economische gevolgen van verschillende klauwaandoeningen, zowel klinisch als subklinisch. De economisch gevolgen, die optreden door de aanwezigheid van de verschillende klauwaandoeningen, zijn gemodelleerd met het ontwikkelde bio-economisch simulatiemodel. De volgende kostenfactoren zijn hierbij onderscheiden: kosten als gevolg van melkproductieverliezen, vervroegde afvoer,

verlengde tussenkalftijd, arbeid van de melkveehouder, kosten voor de klauwbekapper, visite van de dierenarts, behandelingskosten (bijv. antibiotica) en weggegooide melk. De basisberekening gaat uit van een standaard Nederlands bedrijf (ligboxenhuisvesting, betonnen (rooster)vloer, beweiding tijdens zomermaanden en twee keer per jaar klauw bekappen van alle koeien) met 65 koeien onder een melkquotum. Voor dit basisbedrijf waren de kosten gemiddeld €3.474 per jaar, variërend van €2.282 tot €4.965; een jaarlijks verlies van €53 per gemiddelde koe in de koppel. De kosten van subklinische klauwaandoeningen zijn goed voor 32% van alle kosten als gevolg van klauwaandoeningen. Dit betekent dat de kosten als gevolg van klauwaandoeningen, die aanwezig zijn zonder behandeling of detectie door de melkveehouder, aanzienlijk zijn. Deze uitkomst geeft aan dat de voordelen van eerder en grondiger actie nemen door melkveehouders kan worden onderschat. De hoogste kosten, ingedeeld naar klauwaandoening, waren die voor digitale dermatitis (DD, ziekte van Mortellaro), een aandoening met een hoge incidentie en een relatief hoge klinische prevalentie. De hoogste kosten, ingedeeld naar kostenfactoren, waren de melkproductieverliezen en afvoer. De gevoeligheidsanalyse liet zien dat variabelen gerelateerd aan melkproductie belangrijk waren voor de economische kosten als gevolg van klauwaandoeningen. De kansen op het krijgen van een klauwaandoening en de kansen op genezing waren ook belangrijk voor het schatten van de kosten als gevolg van klauwaandoeningen. Deze studie toonde de aanzienlijke impact van klauwaandoeningen voor de melkveehouder.

De tweede stap om meer inzicht te geven in het probleem van klauwaandoeningen was gericht op de impact van klauwaandoeningen op de koe. De doelstelling van hoofdstuk 3 was daarom om de welzijnsimpact van de zeven onderscheiden klauwaandoeningen in te schatten. De impact van de verschillende klauwaandoeningen op welzijn is ingeschat door de incidentie, duur en ernst van de klauwaandoeningen mee te nemen. Voor elke klauwaandoening in klinische en subklinische status werd de score voor pijn ingeschat en gebruikt in het simulatiemodel. Deze pijnscore werd gebaseerd op de geschatte locomotie en de pathofysiologie van de klauwaandoeningen, gebruikmakend van de wetenschappelijke literatuur en de visie van experts. In een ideale situatie bevat een welzijnsinschatting de drie verschillende aspecten van dierenwelzijn; functioneren en gezondheid, het aspect van gevoel (of beleving) en het aspect van natuurlijkheid. Er was echter te weinig informatie beschikbaar om deze verschillende aspecten te modelleren. De pijn van de klauwaandoeningen is daarom gebruikt als indicator, omdat werd aangenomen dat de pijn de impact op alle drie de welzijnsaspecten weerspiegelt. De negatieve impact op welzijn werd gemeten op een schaal van 0 tot 60, waar de maximale uitkomst een koe representeert met zeer ernstige pijn gedurende een heel jaar. Gemiddeld genomen krijgt een koe in de koppel een negatieve impactscore van 12, hetgeen 20% is van de maximale welzijn impactscore. Deze score is gelijk aan het hebben van ernstige pijn voor een periode van drie maanden, wat een serieuze impact op het welzijn betekent. Gemiddeld heeft DD de grootste impact op welzijn, wat wordt veroorzaakt door een hoge incidentie van het pijnlijke klinische stadium. Daarna hebben zoolbloedingen (SoH) en interdigitale dermatitis en balhoornerosie (IDHE) de meeste impact. De combinatie van een hoge incidentie en lange duur van SoH en IDHE zorgen voor deze relatief hoge welzijnsimpact van deze klauwaandoeningen die vooral subklinisch voorkomen. Gemiddeld genomen over een jaar, wordt 46% van de welzijnsimpact als gevolg van klauwaandoeningen veroorzaakt door klinische klauwaandoeningen. De bevinding dat subklinische klauwaandoeningen ongeveer evenveel impact hebben als klinische klauwaandoeningen wijst er op dat melkveehouders de welzijnsimpact van klauwaandoeningen behoorlijk onderschatten. De individuele gevallen van klauwaandoeningen, die de welzijnsimpact op de individuele koe vertegenwoordigen, benadrukken de ernst van pijn intensiteit en de impact van klinische klauwaandoeningen. Daarnaast laat de studie zien dat de benadering voor de welzijnsinschatting, bijvoorbeeld door de keuze voor een benadering op koppel- of koe niveau, de rangschikking van de klauwaandoeningen gerangschikt naar impact op dierenwelzijn beïnvloedt. Verschillende benaderingen leiden mogelijk tot een andere prioritering van oplossingsstrategieën voor melkveehouders, bijv. meer focus op koe comfort, of op hygiëne, klauw bekappen, gezondheidsmonitoring of specifieke curatieve behandelingen. De resultaten voor zowel de economische gevolgen als de impact op dierenwelzijn laten zien dat klauwaandoeningen in de melkveehouderij een aanzienlijk probleem vormen.

Na inzicht te hebben verkregen in gevolgen van klauwaandoeningen, zijn de effecten van interventiemaatregelen ter verbetering van klauwgezondheid ingeschat. De doelstelling van hoofdstuk 4 was om kosten en baten van verschillende interventiemaatregelen ter verbetering van klauwgezondheid in te schatten, zowel voor economie als welzijn. Interventiemaatregelen werden gemodelleerd als ze toepasbaar waren op een bedrijf met ligboxenhuisvesting en als er voldoende informatie beschikbaar was in de literatuur. Netto kosten werden berekend als het verschil tussen de kosten van het nemen van de maatregel en de economische baten die resulteren als gevolg van de maatregel. Welzijnsbaten werden berekend door de negatieve welzijnsimpact van de basissituatie te vergelijken met de geschatte impact na het uitvoeren van de maatregel. De uitkomsten van het modelleren gaven aan dat het verbeteren van de ligplaatsen (matras en strooisel) en het toepassen van aanvullend klauw bekappen kosteneffectieve maatregelen waren. Het verlagen van de bezettingsgraad werd berekend als een maatregel met een break-even resultaat. De verbetering van de ligplaats en het verlagen van de bezettingsgraad hebben ook een relatief groot welzijnsvoordeel. Meer inzicht in de kosteneffectiviteit en welzijnsbaten van interventiemaatregelen kan helpen in de prioritering bij het kiezen tussen interventiemaatregelen.

Na de modelstudies in het eerste onderdeel, die inzicht verschaften in de huidige situatie met betrekking tot klauwgezondheid van melkvee, gaat het tweede onderdeel over de sociale en morele aspecten. Het proces van het modelleren van de welzijnsimpact van klauwaandoeningen op melkvee leidde tot de vraag op het vervroegd afvoeren als gevolg van klauwaandoeningen het welzijn aantast. De aanwezigheid van een klauwaandoening tast het welzijn van de koe al aan, maar vooral de ernstige en terugkerende klauwaandoeningen leiden vaak tot de beslissing om een koe vervroegd af te voeren en tasten de levensduur van de koe aan. In hoofdstuk 5 wordt onderzocht of levensduur zowel een moreel relevant aspect is in de discussie over het doden van dieren als een wezenlijk element van dierenwelzijn, in plaats van alleen een indicator van dierenwelzijn. Om dit te onderzoeken zijn twee stappen genomen. De eerste stap omvat een verandering in het concept van dierenwelzijn; van een concept dat voornamelijk wordt gebaseerd op biologische kennis naar het idee dat dierenwelzijn is gebaseerd op biologische kennis maar in gelijke mate wordt bepaald door morele normen. De tweede stap omvat een verandering in de visie op welzijn; van een visie gebaseerd op functioneren en gevoel naar een visie op welzijn die het aspect van natuurlijkheid bevat, waar soort-specifieke voorkeuren en soort-specifieke ontwikkeling belangrijk zijn. Op basis van normatieve en biologische argumenten, wordt gesteld dat dierenwelzijn meer integraal benaderd zou moeten worden en dat het over een periode van tijd beoordeeld zou moeten worden. Deze interpretatie is onafhankelijk van de capaciteit van dieren om het concept leven te begrijpen of besef te hebben en zich te kunnen richten op de toekomst. In de praktijk betekent het opnemen van levensduur in de welzijnsbeoordeling dat vervroegd afvoeren, i.e. het afvoeren van een dier voordat de beoogde productieleeftijd is bereikt, geen neutrale handeling is maar een handeling die het dierenwelzijn aantast vanwege de implicaties voor de levensverwachting van een koe. Dit verbreedt de werkingssfeer van de evaluatie van klauwaandoeningen. In plaats van de focus op de vraag of een klauwaandoening effect heeft op de mogelijkheid van een koe om te functioneren in een bepaald systeem, vraagt deze visie een beoordeling waarin alle belangen van het dier, inclusief die relateren aan levensduur, serieus genomen worden.

Om klauwgezondheid van melkvee te verbeteren is het belangrijk om rekening te houden met de houding en intentie van melkveehouders met betrekking tot dit onderwerp. De doelstelling van hoofdstuk 6 was om inzicht te verkrijgen in de houding van melkveehouders met betrekking tot klauwaandoeningen bij melkvee en hun intentie om actie te nemen voor verbetering van klauwgezondheid. De Theory of Planned Behavior (TPB) is gebruikt om ‘drivers’ en ‘barriers’ voor het nemen van actie te bepalen. Dit kader van de TPB is uitgebreid met vragen over persoonlijke normatieve overtuigingen, welke meer vertellen over de persoonlijke waarden van melkveehouders over dierenwelzijn en morele verplichtingen tegenover dieren. Een dergelijk kader geeft informatie om oplossingsstrategieën voor te stellen voor de verbetering van klauwgezondheid bij melkvee. Vijfhonderd melkveehouders zijn willekeuring geselecteerd en zijn per email uitgenodigd om de enquête online in te vullen. De enquête bevatte vragen over de intentie, houding, ‘subjective norm’, ‘perceived behavioral control’ en vragen over de persoonlijke normatieve overtuigingen. De resultaten (respons van 30%) lieten zien dat bijna 70% van de melkveehouders een intentie heeft om actie te nemen om de klauwgezondheid van melkvee te verbeteren. Echter, de meeste melkveehouders leken tevreden met de klauwgezondheidsstatus op het bedrijf en dat verzwakt de intentie om actie te nemen. Het behalen van een betere klauwgezondheid met kosteneffectieve maatregelen leek de belangrijkste 'driver' te zijn. Mogelijke 'barriers' voor het nemen van actie waren arbeidsefficiëntie en het effect dat het nemen van actie pas op langere termijn effect heeft op de klauwgezondheidsstatus. De voeradviseur en de klauwbekapper lijken het meest invloed te hebben op de intenties van melkveehouders om actie te ondernemen ter verbetering van de klauwgezondheid van hun melkvee. Subklinische klauwaandoeningen werden niet als belangrijk beschouwd voor dierenwelzijn. Bovendien antwoordde 25% van de respondenten dat koeien geen pijn kunnen lijden. De visie op welzijn was voornamelijk gebaseerd op de beperkte visie van gezondheid en functioneren. De meeste melkveehouders gaven aan dat goede zorg voor de koeien belangrijk is, maar dit was niet geassocieerd met de intentie om klauwgezondheid te verbeteren. De kosteneffectiviteit van te nemen maatregelen leek belangrijker te zijn voor de intentie om actie te nemen voor klauwgezondheidsverbetering. Het verschaffen van meer informatie over de effecten van het nemen van interventiemaatregelen zou melkveehouders kunnen stimuleren om actie te nemen voor de verbetering van klauwgezondheid bij melkvee.

Hoofdstuk 7 bediscussieert de methoden en uitkomsten van de voorgaande hoofdstukken, gevolgd door een discussie over de rol van de melkveehouder. Op basis van dit proefschrift kan worden geconcludeerd dat de impact van klauwaandoeningen aanzienlijk is, zowel de economische gevolgen voor de melkveehouder als de welzijnsimpact op de koe. De aanzienlijke impact van subklinische klauwaandoeningen betekent dat het waarschijnlijk is dat de impact groter is dan betrokkenen zich bewust zijn. Daarnaast lieten de resultaten zien dat maatregelen ter verbetering de klauwgezondheid tot op zekere hoogte zullen verbeteren. Echter, de meeste maatregelen leken niet kosteneffectief te zijn. Bij het maken van de inschattingen bleek dat het behoorlijk lastig is om een inschatting te maken van de impact, zowel voor de impact van de klauwaandoeningen als voor de effecten van de maatregelen ter verbetering van de klauwgezondheid van melkvee. Ontbrekende kennis over dit onderwerp is aan het licht gebracht en richtingen voor nieuwe studies zijn geduid. De meeste melkveehouders hadden intentie om de klauwgezondheid van hun melkvee te verbeteren, echter, de intentie was matig. Daarnaast leek het erop, dat de maatregelen die andere inzet vroegen dan de routinematige of al bekende maatregelen, geen optie waren voor de meeste melkveehouders. Dit proefschrift eindigt met de vraag: wat kunnen we redelijkerwijs verwachten van melkveehouders met betrekking tot het verbeteren van klauwgezondheid bij melkvee? Gebaseerd op de ontwikkelingen in hoe we dieren waarderen en omgaan met dieren, kan worden geconcludeerd dat de huidige situatie met betrekking tot de klauwgezondheid van melkvee niet acceptabel is. De melkveehouder is de degene die verantwoordelijk is voor een goede gezondheid en welzijn van het melkvee. De interpretatie van dierenwelzijn door melkveehouders verschilt echter van het bredere concept dierenwelzijn zoals in dit proefschrift voorgesteld en is ook anders dan de interpretatie die de meeste mensen in de samenleving hebben. Daarnaast moet een melkveehouder het belang om klauwgezondheid te verbeteren wegen ten opzichte van andere issues op het bedrijf. Om verbetering te bereiken in de melkveehouderij, is het belangrijk dat de hele sector erkent dat dierenwelzijn een begrip is dat meer inhoudt dan gezondheid en functioneren. Dit zal het belang om klauwgezondheid te verbeteren vergroten, waardoor het een hogere prioriteit krijgt om gezamenlijk actie te ondernemen.

Curriculum vitae

About the author

Maria Reijertje Neeltje (Mariëlle) Bruijnis was born on the 18th of October 1983 in Heemstede, The Netherlands. She grew up in Nieuw-Vennep where she completed secondary school at Herbert Vissers College in 2001. The same year she started the study Animal Sciences at Wageningen University. Her first master thesis, in the field of ethology and animal welfare, was on the subject 'Motivation, physical abilities and differences between male and female broilers'. She did her second master thesis at the chair Animal and Society, where she performed the research assignment entitled 'Pasturing and housing of dairy cattle' at the Dutch Council for Animal Affairs. After graduation in 2006 she started to work as a policy employee at the Product Boards for Livestock, Meat and Eggs. In June 2008 she started as PhD student at the chair Animal and Society of Wageningen University. This research aimed at improvement of dairy cattle welfare by a socio-economic approach on the problem of foot disorders and lameness in dairy cattle and is described in this thesis.

Over de auteur

Maria Reijertje Neeltje (Mariëlle) Bruijnis werd geboren op 18 oktober 1983 in Heemstede. Zij groeide op in Nieuw-Vennep waar zij in 2001 haar gymnasium diploma behaalde aan het Herbert Vissers College. In hetzelfde jaar begon zij aan de studie Dierwetenschappen aan Wageningen University. Ze deed haar eerste afstudeervak, op het gebied van ethologie en dierenwelzijn, op het onderwerp 'Motivatie, fysieke mogelijkheden en verschillen tussen hanen en hennen bij snelgroeiende vleeskuikens'. Haar tweede afstudeervak deed ze bij de leerstoel Dier en Samenleving, waar ze de onderzoeksopdracht 'Weidegang en opstallen van melkvee' uitvoerde bij de Raad voor Dierenaangelegenheden (RDA). In 2006 studeerde zij af en begon dat zelfde jaar als beleidsmedewerker bij de Productschappen voor Vee, Vlees en Eieren. In juni 2008 begon zij als promovenda bij de leerstoel Dier en Samenleving van Wageningen University. Dit onderzoek is gericht op de verbetering van het welzijn van melkvee door een socio-economische benadering van klauwproblemen en kreupelheid bij melkvee en is beschreven in dit proefschrift.

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Bruijnis MRN, Hogeveen H and Stassen EN, 2010. Assessing economic consequences of foot disorders in dairy cattle using a dynamic stochastic simulation model. Journal of Dairy Science 93, 2419-2432. DOI: 10.3168/jds.2009-2721

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Training and Supervision Plan

Name: Mariëlle Bruijnis

Chair: Animal and Society

Description (ECTS credits*)	**Year**
The Basic Package (3.0)	
WIAS Introduction Course	2008
Course on philosophy of science and/or ethics	2009 - "10
Scientific Exposure (15.0)	
International conferences	
International workshop on Farm Animal Health Economics (ONIRIS) Nantes, France	2010
Congress of the International Society of Applied Ethology (ISAE) Uppsala, Sweden	2010
Cattle Lameness Conference Nottingham, United Kingdom	2011
Universities Federation for Animal Welfare (UFAW) conference Portsmouth, United Kingdom	2011
Minding Animals Conference Utrecht, The Netherlands	2012
Seminars and workshops	
WIAS Science day Wageningen, The Netherlands	2010 - "12
Symposium over vragenlijsten in survey-onderzoek (NPSO) Amsterdam, The Netherlands	2009
Workshop 'Motivating the farmer beyond the economic ratio' (UU) Utrecht, The Netherlands	2009
'Studiedag kreupelheidsdetectie bij melkvee' (ILVO) Merelbeke, Belgium	2009
Symposium 'Meer welzijn zonder pijn' (Wageningen UR Livestock Research) Lelystad, The Netherlands	2010
Symposium 'Klauwgezondheid bij melkvee' (dierenartsenpraktijk Arts&Dier) Hardenberg, The Netherlands	2010
Kick-off meeting 'Grip op klauwen' (ZLTO) Bunschoten, The Netherlands	2011
Presentations	
Oral presentation studiedag ILVO	2009
Oral presentation international workshop ONIRIS	2010
Oral presentation ISAE	2010
Oral presentation symposium Arts&Dier	2010
Poster presentation WIAS Science day	2011
Poster presentation Cattle Lameness Conference	2011
Oral presentation UFAW conference	2011
Oral presentation WIAS Science day	2012
Oral presentation Minding Animals Conference	2012

In-Depth Studies (18.3)	
Disciplinary and interdisciplinary courses	
Animal Health Economics I	2008
Animal Health Economics II	2009
Quantitative Veterinary Epidemiology	2009
Introduction to social science research methodology for use in veterinary epidemiologic research	2009
Animal & Nature Ethics (tailor made)	2009 - "10
PhD students' discussion groups	
Journal discussion group, Utrecht University	2008 - "09
PhD welfare discussion group (incl. chair), Wageningen University	2009 - "11
Professional Skills Support Courses (4.1)	
Individual coaching	2007 - "08
Project working	2008
PhD competence assessment	2009
Techniques for writing and presenting a scientific paper	2009
Career orientation	2012
Research Skills Training (6.0)	
Preparing own PhD research proposal	2008
Didactic Skills Training (3.9)	
Lecturing for 'Health, Welfare and Management'	2010 - "11
Supervising BSc thesis	2009
Coach farm project 'Introduction Animal Sciences'	2008 - "09,"11
Coach farm project 'Integrated Course Ruminants'	2011 - "12
Coach 'Adaptation Physiology II'	2011 - "12
Management Skills Training (2.0)	
Membership WAPS council, incl. Education Committee	2011
Education and Training Total: 52.3 credits	

* One ECTS (European Credit Transfer System) credit equals a study load of approximately 28 hours.

Colophon

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