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Effectiveness of animal health and welfare planning in dairy herds: a review

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Abstract

Maintaining and promoting animal health and welfare are important but challenging goals in livestock farming. Animal health and welfare planning aims to contribute to improvements in the herd through interventions in a structured way. This review provides an overview of current scientific approaches to and improvements achieved by health and welfare planning in dairy herds regarding the health and welfare state of the cows, economic effects, and non-monetary benefits to farmers. Implementation of changes in management and housing is based on an assessment of the health and welfare state and relies on the participation of all involved persons. Farm-specific measures of management and housing, high levels of compliance with those measures, continuous review, and prompt adaptation are decisive. Improvements in health and welfare following the use of planning have been shown by several on-farm studies, especially in the context of mastitis and lameness. Studies on health and welfare planning that consider a more comprehensive view of welfare are scarce and the limited evidence available indicates that improvements may be less likely to be achieved. Apart from health and welfare benefits for the animals, economic and non-monetary benefits for the farmers are equally important. Costs of diseases and impaired health are available, while costs and benefits of interventions have been estimated with regard to mastitis and lameness only. Non-monetary factors (eg job satisfaction) have been reported as motivating factors for farmers but have attracted little scientific interest. Further research should focus on welfare aspects that go beyond the most important production diseases and the economic and non-monetary benefits of improving health and welfare in dairy cattle.

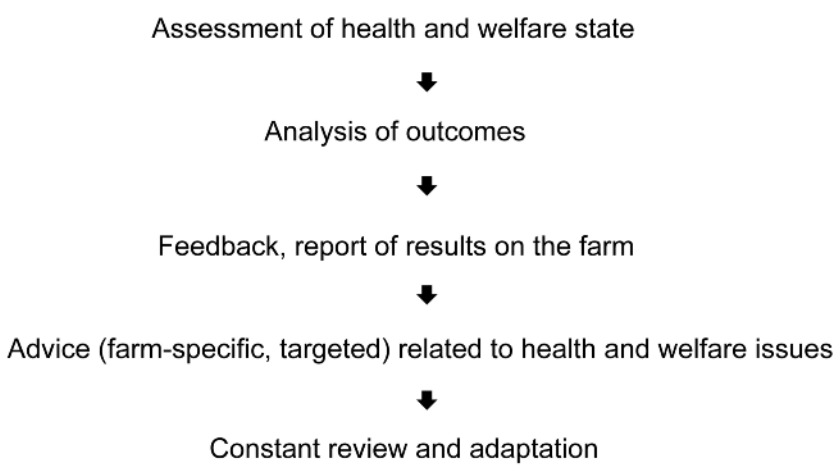
Keywords: *animal welfare, costs, dairy cows, improvement strategies, non-monetary benefits, on-farm welfare assessment*

Introduction

Animal welfare has received increased attention among European consumers (European Commission 2007), and during the last two decades farm animal welfare science has evolved into a well-recognised scientific discipline (Millman *et al* 2004). While welfare-friendly housing systems and management procedures (eg studies on cow comfort; Cook & Nordlund 2009) have been developed, surveys indicate that health problems, such as lameness, mastitis or skin lesions, are still highly prevalent and often exceed expert-derived intervention thresholds (eg Whay *et al* 2003; Green *et al* 2007; Leach *et al* 2010a; von Keyserlingk *et al* 2012). Beyond this focus on animal health (biological functioning), a more comprehensive approach in defining animal welfare also includes the animals' feelings (affective state) and their ability to express natural behaviour (natural living) (Fraser *et al* 1997). However, surveys on the latter two areas are rare and cover only parts of it (eg von Keyserlingk *et al* [2012] on lying times in dairy cattle). Although it may seem tautological to use the term 'animal health and welfare planning', as health is one of the three aspects of animal welfare, we keep this term throughout this paper to make explicit that we are discussing all aspects of animal welfare. Moreover, most health and welfare planning activities that will be discussed in the present review had a strong focus on promoting animal health or on increasing welfare through enhancing health parameters. Substantial progress in developing valid, reliable and feasible assessment systems has been made (Main *et al* 2007; Knierim & Winckler 2009), but more effort is needed to actually improve animal welfare (Whay 2007). Assessing the health and welfare state and identifying and implementing appropriate interventions on-farm have received increased attention during recent years.

In dairy cattle, farmers, veterinary and agricultural advisors, and scientists have focused particularly on lameness (eg Whay *et al* 2003) and mastitis (eg Green *et al* 2007). However, despite a vast body of scientific evidence on (potential) risk factors, the implementation in terms of changes in housing conditions and management on-farm appears still inadequate (Valeeva *et al* 2007; Whay & Main 2010). Hence, improving health and welfare of dairy cows seems to rely on getting information across to farmers in a more suitable way and in encouraging decisions in favour of the animals (Jansen *et al* 2009; Garforth 2011).

Figure 1



Key features of animal health and welfare planning.

Animal health and welfare planning appears to be a promising way to achieve this. It is a structured process that builds on assessment of health and welfare, identification of risk factors, development and implementation of interventions, and constant review and evaluation. Animal health and welfare planning thus goes beyond the approach of herd health plans which were developed in the UK during the last two decades and became a significant part of UK farm assurance schemes (Nicolas & Jasinska 2008).

Although planning strategies for implementing changes directed at welfare improvements in dairy farms exist, few studies have analysed how effective these interventions were. Besides, an improved welfare state of dairy cows, economic and social benefits, such as increased productivity and enhanced work satisfaction, may arise for the farmers. Although research into motivating factors and incentives has shown a number of non-monetary incentives for improving animal welfare (Valeeva *et al* 2007; Leach *et al* 2010b), these benefits have been barely investigated.

This review discusses existing studies on animal health and welfare planning in dairy herds with a focus on the evaluation of their effectiveness concerning animal welfare improvements, as well as economic and non-monetary benefits to farmers. Moreover, it covers key features of health and welfare planning and discusses the implementation of measures with respect to housing and management. Furthermore, this review provides insights into methodological aspects of measuring efficiency and identifies factors for successful animal health and welfare planning.

Key features of animal health and welfare planning

Several scientific studies have covered different aspects of health and welfare in dairy herds and have applied different planning strategies (eg Vaarst *et al* 2007; Bell *et al* 2009; Brinkmann & March 2010). These approaches have either focused on single welfare concerns or on more comprehensive planning. Comprehensive approaches consider welfare issues besides health-related issues in the planning process, and a multitude of areas are covered simultaneously. In both cases, there exist common features as outlined below (Figure 1).

Assessment of health and welfare state

An initial part of all studies is the assessment of current health and welfare in order to find and implement management changes for welfare improvement. In most instances, the existing animal welfare systems focus on negative welfare states rather than aspects of positive welfare. However, there is increasing interest in positive welfare that goes beyond the prevention of impaired negative states (Boissy *et al* 2007), but knowledge on its assessment and on improvement strategies is still lacking. Early concepts of on-farm animal welfare assessment such as the 'Animal Needs Index' ANI-35 (Bartussek 1999) mainly focused on resource-based parameters addressing housing and management provisions (see Table 1). Similarly, farm assurance schemes developed (mainly in the UK) with the aim of assuring welfare, environmental, and food safety standards have also relied heavily on resource-based measures. They were used as veterinary tools to ensure acceptable levels of animal welfare and were oriented at assessing the husbandry provision (Main *et al* 2003). Resource-based protocols can easily be applied on-farm with considerable reliability but questionable validity, as they are only indirectly linked to the animals' welfare state (Alban *et al* 2001; Waiblinger *et al* 2001). Welfare as a multi-dimensional construct that includes the animals' emotional state and their ability to behave naturally requires more direct ways of assessment. Animal-based parameters are meant to better reflect how the animals are coping with their environment (Whay *et al* 2003). These parameters may be roughly divided into health- and behaviour-related measures (Table 1), with lameness, mastitis or skin injuries being typical examples of health-related measures. Animal-based parameters can either be assessed directly from the animal (via examination or observation) or through routinely

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Table 1 Overview of animal- and resource-based measures for assessing health and welfare of dairy cows.

Type of measures	Parameter	Reference
Animal-based measures		
Health-related	Locomotion score	Winckler & Willen (2001); Whay *et al* (2003); Flower & Weary (2009)
	Mastitis incidence*	Green *et al* (2007); Ivemeyer *et al* (2009)
	Mortality*	Welfare Quality® (2009)
	Integument alterations, injuries	Weary & Taszkun (2000); Rutherford *et al* (2008); Brenninkmeyer *et al* (2013)
	Body condition score	Welfare Quality® (2009)
	Cleanliness of animals	Zurbrigg *et al* (2005)
Behaviour-related	Incidence of agonistic behaviour	Welfare Quality® (2009)
	Avoidance distance towards humans	Windschnurer *et al* (2008)
	Lying down behaviour	Pleasch *et al* (2010)
	Standing up behaviour	Chaplin & Munksgaard (2001)
	Lying time	Ito *et al* (2009)
	Qualitative behaviour assessment	Wemelsfelder *et al* (2001)
Resource-based measures		
	Provision of water	Welfare Quality® (2009)
	Access to outdoor loafing area, pasture	Welfare Quality® (2009)
	Design criteria (eg type of housing system, dimensions of cubicles, alleys)	Bartussek (1999); Welfare Quality® (2009)
	Floor condition	Bartussek (1999)
	Cleanliness of lying area	Bartussek (1999)
	Ventilation system	Bartussek (1999)

* Parameter obtained through routine collection of health data.

collected data (such as treatment incidences, or mortality rates). 'Affective states' could for instance be assessed through qualitative behaviour assessment or measuring the avoidance distance towards humans whereas, for example, lying behaviour or agonistic social behaviour would be assessments of 'natural living' (Fraser *et al* 1997). The Welfare Quality® assessment protocols (Welfare Quality® 2009) represent a mostly animal-based assessment approach and cover several livestock categories, including dairy cows. Designed for practical on-farm conditions, animal-based indicators are combined with measures in housing and management (Bracke 2007; Whay 2007) as well as using databases and farm records for insights into production level and treatment data (Ivemeyer *et al* 2007).

Analysis of outcomes and provision of feedback

Following the assessment, the outcomes are analysed and reports created and given back to the farmer (Figure 1). The report should act as a decision support tool on the farm, and the structure has to be readable and problem-oriented (Bonde *et al* 2001; Vaarst 2003). A well-balanced welfare report should thus give an overview as well as being comprehensive enough to provide detailed information on specific welfare concerns, which is essential for achieving welfare benefits (Bonde *et al* 2001; Bell *et al* 2006). In many cases, a benchmarking reporting system was used to allow comparison between the farms in question (Whay *et al* 2003; Brinkmann & March 2010; Ivemeyer *et al* 2012; von Keyserlingk *et al* 2012). Benchmarking can demonstrate what might be achievable through implementing specific measures (Huxley *et al* 2004), and it is a method to encourage farmers to participate in animal health and welfare planning (Gray & Hovi 2002).

Farm-specific, targeted advice

Knowledge of the actual health and welfare states of the animals will simultaneously serve as the basis for attempts to improve health and welfare. Advising in terms of proposing measures derived from experimental studies or from practical experience has for a long time been seen as a way of disseminating knowledge. For example, in a mastitis control study, Green *et al* (2007) involved two veterinary surgeons who were in charge of creating a mastitis diagnosis and control plan for the 52 participating farms. It was the veterinarians' task to come up with measures that were then presented to the farm personnel, and compared to

already existing preventive measures on the farms. Across the 26 intervention farms, Green *et al* (2007) achieved an equal number of farms that implemented more than two-thirds, between one- and two-thirds, and less than one-third of the measures (such as improvements in post-milking teat disinfection, milking machine function, or detection of mastitis cases) after one year. Using a similar approach, Barker *et al* (2012) presented recommendations to the farmers participating in a lameness control study. Based on an assessment of the farm and an evaluation of possible risk factors, improvement measures were proposed to the farmers by one of the researchers. The farmers could then either agree, disagree, or state that they were uncertain about implementing the recommended changes. This resulted in an overall level of compliance with the recommended measures of 31%. In both studies, advice was always provided by external experts or scientists. Similarly, Main *et al* (2012) encouraged farmers with respect to taking action in lameness management and potential benefits and barriers of the whole process were discussed. The researchers had a comprehensive overview of good husbandry practice on other farms and used that insight in the discussion. However, a key aspect of animal health and welfare planning is the inclusion of all involved parties in the process of implementation, comprising, eg veterinary surgeons, nutritional consultants, and agricultural advisors. This was taken up by a UK study on dairy heifer lameness (Bell *et al* 2009) where the unique farmer-veterinarian pair was responsible for agreeing on the lameness action plan and measures that could realistically be implemented. The programme was based on an analysis of hazards and critical control points, and the results were reported on the farms by their regular veterinary surgeons. However, they reported 'less than satisfactory' concordance with lameness control plans. No farm complied with all areas agreed upon, and most farms implemented less than two elements of the plan.

The farmer has been identified as the main stakeholder in promoting animal welfare (Gray & Hovi 2002; Whay & Main 2010; Vaarst *et al* 2011), and especially the steps of setting targets at what to improve and developing suitable intervention measures on the farm require the full inclusion and motivation of all participants. Therefore, an even more interactive planning approach involves the participating farmers and their wishes and expectations in the planning step. This approach has resulted in farmer-owned decisions on problem areas that require improvement. Consequently, it is also up to the farmers to formulate suitable intervention measures while external persons, ie the advisors or researchers, act as facilitators and may support decisions with external knowledge. Recent studies have covered more comprehensive health and welfare planning (Brinkmann & March 2010; Gratzer 2011). Depending on the focus area of the health and welfare plan, Gratzer (2011) reported degrees of implementation between 67 and 44% for udder health and fertility, respectively. Implementation rates increased with time in Brinkmann and March (2010) with 32 and 72% one and five years, respectively, after measures for a range of health and welfare concerns had been discussed.

All the above-mentioned ways of communicating and advising can be extended to groups acting in the process of animal health and welfare planning. The so-called 'Stable Schools', first introduced by Vaarst *et al* (2007), builds on this approach. Guided by a facilitator, participating farmers form groups where they jointly become involved in setting goals on what to improve and developing measurements to examine change. The facilitator's role is to help the group maintain a fruitful discussion, and not to act as an advisor who disseminates knowledge and advice. It is important to have in mind the farmers' ownership of his or her farm and the farm-specific goal (eg minimising antibiotic treatment in dairy cattle; Vaarst *et al* [2007]). Attention has to be turned to an ongoing dialogue between the farmers in a group. Each of the participants shares and receives information and knowledge at the same time.

Measures for improvement, irrespective of the method of communication, need to be valid with regards to their potential effect and the number of measures addressing a specific health or welfare issue depends on the farm-specific situation and the problem itself. Measures applied in health and welfare planning can be derived from a pool of measures that are based on sound scientific findings (eg Telezhenko *et al* 2009; von Keyserlingk *et al* 2012; Brenninkmeyer *et al* 2013) or on farming expertise. However, choosing appropriate measures is not always a clear decision as knowledge on various management procedures, housing standards and technologies changes over time or effectiveness depends on the specific circumstances on the farms. For instance, Barker *et al* (2012) express doubts that all measures recommended for reducing claw lesions are beneficial for the cows. Although intended to increase lying comfort, the abrasive properties of sawdust as a bedding material deteriorated leg health. Such unintended consequences of recommendations may therefore explain a lack of positive effects on health and welfare and should be taken carefully into account (Bell *et al* 2009).

Continuous review and adaptation

Continuous review of a plan once established is decisive as health and welfare states undergo frequent changes and are not constant. A constant review process is essential to monitor targets established in the health and welfare plan, which allows for adaptations whenever targets are not met (Vaarst *et al* 2011). Reviews should take place annually or even more frequently to take seasonal variation into account (Bell *et al* 2006; Sibley 2006).

Evaluation of effectiveness

Measures developed during the planning process can only effectively improve health and welfare if they are actually implemented on-farm. The degree of implementation can thus be regarded as a measure of success. However, as outlined in the previous section, implementation rates vary considerably and not all studies report the levels of compliance. Reasons for varying degrees of implementation will be further discussed in due course (see *Success and risk factors for health and welfare improvement*). Most studies

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investigating animal health and welfare planning have focused on the assessment of possible improvements regarding the health and welfare of the animals themselves. However, in the following section we also regard a broader range of aspects, such as cost-benefit analyses and non-monetary benefits to the farmers that are important for a comprehensive evaluation.

Animal health and welfare improvements

Mastitis is often an important component of studies on health planning approaches, and these have demonstrated that successful improvement of udder health can be achieved. Focusing on clinical mastitis, Green *et al* (2007) implemented a mastitis control plan intervention on 26 UK dairy farms that did not differ significantly from a control group in herd size, milk yield or in the total incidence of clinical mastitis and the proportion of cows affected by clinical mastitis at the start of the study. During a one-year period, the mean incidence of cows affected by clinical mastitis as well as the mean incidence of clinical mastitis decreased on the intervention farms, on average, by 4% and increased on the control group farms by 19 and 18%, respectively. Level of compliance with the mastitis control plan is important, however. Farms with more than two-thirds of the measures implemented achieved a reduction in both the number of cows affected and the total number of mastitis cases of about 20%. Udder health deteriorated slightly in low-compliance farms (less than one-third of the measures implemented).

On 65 Swiss farms, which implemented changes in housing and management after a structured evaluation (such as improving housing conditions, milking technology or feeding management), the use of antibiotic treatments for mastitis decreased from 38.1 to 26.2 treatments per year per 100 cows within a two-year period (Ivemeyer *et al* 2008). When analysing the first year separately (Ivemeyer *et al* 2009), these improvements were not as pronounced as after two years. At the same time, bulk milk somatic cell count (BMSCC), as a means of assessing (subclinical) udder health, did not change significantly (178,000 vs 181,000 cells per ml in year 0 and year 2, respectively). A reduction in the use of antibiotics for mastitis treatment by approximately 50% was also achieved through the implementation of a one-year 'Stable School' (Vaarst *et al* 2007; Bennedsgaard *et al* 2010).

While tackling mastitis through structured planning processes seems to be promising, the effects of animal health and welfare planning on dairy cattle lameness as another significant welfare concern are ambiguous. Lameness prevalence decreased by about 12 percentage points over a three-year period on farms (n = 117) that received support from the research team on how to improve foot health as well as on farms (n = 72) which were only monitored (Main *et al* 2012). Baseline lameness prevalence was slightly, but significantly, lower in the support group than in the control group. When accounting for initial lameness, a significant interaction between year and support, a more pronounced reduction in lameness over time in the supported group was found. However, a clear reduction in lameness prevalence was achieved in the course of a four-year lameness intervention study on German organic dairy herds (Brinkmann & March 2010). In accordance with the farm managers' interests and motivation, the farms were allocated to either an intervention or a control group with 21 and 19 farms, respectively. Baseline levels of lameness were higher in intervention farms, but even when accounting for this effect, lameness prevalence on the intervention farms was significantly reduced (33.0 to 14.5%), whereas the change in the control group was less pronounced (18.5 to 15.4%). These changes were highly consistent over the study period. Besides the changes in lameness prevalence, the occurrence of swellings at the carpal joint was reduced significantly from 25.2 to 8.0% on the intervention farms.

Other studies were less successful in reducing lameness. In a two-year intervention study on heifer lameness that reported low levels of compliance with the changes in housing and management, no significant changes in lameness prevalence were observed (Bell *et al* 2009). A more recent study among 40 UK dairy farms (Barker *et al* 2012), allocated to either an intervention or control group with 22 or 18 farms, respectively, resulted neither in a significant reduction in lameness nor changes in the prevalence of claw lesions.

Studies on more comprehensive animal health and welfare planning are rare, but the results indicate that improvement may be more difficult to obtain when several clinical issues are addressed simultaneously. For example, Ivemeyer *et al* (2012) aimed to reduce medicine use by addressing several health and welfare issues, such as udder health, fertility, metabolic disorders, and lameness on 128 organic dairy farms in seven EU countries. It was up to the participating farmers to choose area(s) of interest and one or several farm-specific goals for improvement. Most frequently, metabolic disorders, udder health and lameness were addressed. The total treatment incidence significantly decreased within the one-year project duration. However, as the vast majority of treatments were related to udder health, medicine use in this area was only significantly lower at the end of the survey period. This was paralleled by a significant improvement of the somatic cell score, again indicating the potential for effective interventions as regards udder health. When the data of 40 German dairy herds participating in the above-mentioned study were analysed separately for intervention effects regarding udder health, metabolic state and reproductive disorders, not only was a significant improvement in udder health found (14 intervention vs 26 control farms), but also treatment incidences of retained fetal membrane and endometritis were lower among the intervention herds (nine intervention vs 31 control farms; Brinkmann & March 2010). Regarding metabolic disorders, only slight and inconsistent changes were obtained. Improvement within a one-year period of comprehensive planning is not always found. For instance, changes in animal health and welfare were not found in the Austrian subsample of 39 dairy herds from the previous study (Gratzer 2011), however, only a small number of

Table 2 Economic costs of lameness and mastitis in dairy cattle as published in peer-reviewed papers.

	Lameness	Mastitis	
		Clinical	Clinical and sub-clinical
Kossaibati & Esslemont (1997)	357†/369‡	265†/316‡	
Enting *et al* (1997)	104†/23‡	–	
Ettema & Østergaard (2006)	192†	–	
Bruijnis *et al* (2010)	57‡	–	
Yalcin (2000)	–	–	233‡
Huijps *et al* (2008)	–	63‡	140‡
Hagnestam-Nielsen & Østergaard (2009)	–	428†/97§	
Hultgren & Svensson (2009)	–	529†/68§	

To facilitate comparison of results all currencies were converted into € (exchange rate used was that for the year of publication).
† Costs per case;
‡ costs per average cow in the herd;
§ costs per cow-year.

farms chose to address a multitude of health and welfare areas at one time. The relatively small sample size, and the fact that few farms addressed welfare-related besides purely health-related issues may explain these results.

Other areas of animal welfare, such as human-animal relationship or the incidence of agonistic interactions, have hardly ever been part of intervention studies. Hemsworth *et al* (2002) achieved behavioural and attitudinal changes in stockpeople toward dairy cattle in an intervention group compared to a control group. As a result, the mean flight distance of the cows, as a means of human-animal relationship, was significantly lower for the intervention group. However, the effect size was small (mean flight distance of 4.49 vs 4.16 m for control and intervention farms, respectively).

Economic effects

The inclusion of disciplines other than agricultural and veterinary sciences and ethics into the process of assessing and improving farm animal welfare has been repeatedly proposed (Lund *et al* 2006; Whay 2007). Economic aspects, however, have only been rarely taken into account in dairy health and welfare planning (Green *et al* 2007). It should be mentioned that economic evaluations are complex, and data on economics in health and welfare planning only exist to a small extent.

Animal health and welfare planning generates costs at different levels. The costs associated with this process can be generally categorised into costs of health and welfare problems, costs of the assessment itself, and costs of intervention measures (eg review on udder health economics by Hogeveen *et al* [2011]). If external advice is requested, the costs of these services have to be considered as well. While on-farm studies with a comprehensive view of welfare have not included economic evaluations, data are available on economic aspects of specific health concerns. For dairy cattle, the impact of mastitis and lameness on farm economics has been addressed specifically (Table 2). Costs of specific diseases vary largely, which may be attributed to different methodological approaches and factors included (Halasa *et al* 2007). This range of costs underlines the economic relevance of these health aspects and indicates that improvements (eg in udder health and lameness) might also be of economic interest.

Economic costs of other diseases have been rarely investigated. Reproductive performance was recently evaluated by Inchaisri *et al* (2010), computing an annual economic loss from poor reproductive performance of €88 per cow. Kossaibati and Esslemont (1997) estimated costs arising from vulvar discharge, retained fetal membrane, and milk fever amount to €235, €120, and €319 per case, respectively. Besides these figures, other areas, for example those related to animal behaviour, have not been analysed with respect to possible economic aspects.

Regarding the costs of the assessment, yearly costs of welfare assessment on dairy farms with automated milking systems have been estimated to amount to €2,430 for herds with 60–120 cows (Sørensen *et al* 2007). However, the true costs are likely to show a wide range as they depend largely on the comprehensiveness of the assessment protocol, labour costs of the assessor, the frequency of farm assessments, the availability of already recorded data from databases, and automation level of data acquisition.

If farmers are to change housing and/or management, decision support for animal health and welfare planning requires precise knowledge about costs of different intervention measures (Huijps *et al* 2010). Standard figures for costs of management routines as well as buildings and equipment are available in some countries (eg KTBL 2010). However, investment costs in particular, may vary to a great extent between countries or regions, while the labour demand for implementing certain management practices rather depends on the production system.

Particularly for mastitis and lameness, costs of interventions have been analysed by two recent studies (Huijps *et al* 2010; Bruijnis *et al* 2013). Labour costs and expenditures for different intervention measures showed considerable variation when computed for a default Dutch dairy farm with 65 dairy cows. For example, yearly costs of 18 management measures for the control of contagious and environmental mastitis pathogens ranged from €34 for rinsing milking clusters after milking cows with clinical mastitis to €7,994 for rinsing milking clusters after milking a subclinical mastitis case (Huijps *et al* 2010). The analysis of interventions for lameness identified measures associated with low annual costs per animal, such as additional foot trimming (€7 per cow per year), whereas labour-intensive management changes led to high costs, eg manual floor cleaning (€56 per cow per year) (Bruijnis *et al* 2013).

Besides the costs arising from the implementation of changes on a farm, benefits resulting from these management or housing changes are also of interest. For lameness, Bruijnis *et al* (2013) estimated the probability of a cow

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becoming lame when different intervention measures were applied. Comparing this situation with the default simulation without intervention revealed measures such as improving the lying surface with mattresses (€7 benefit per cow per year) or bedding (€1 per cow per year) or applying regular foot trimming (€1 per cow per year) as cost-efficient, while reducing stocking density only achieved a break-even.

In recent years, 'technical efficiency' has been developed as a comprehensive approach to investigating a farming system's efficiency. The technical efficiency of farms reflects how well farms convert inputs (such as land, animals, feed, and labour) into outputs (eg milk and milk components) (Stokes *et al* 2007). A widely used method for assessing technical efficiency is the data envelopment analysis, a non-parametric method where no assumptions on the underlying production function have to be made (Cooper *et al* 2003). With this approach, the performance of each dairy farm in terms of technical efficiency can be measured and benchmarked to the other farms in the sample. The outcomes of studies that have applied data envelopment analysis rely to a large extent on the quality and availability of data, and the sample of farms needs to be homogeneous (Dyson *et al* 2001; Barnes 2006). The technical efficiency approach also allows for calculating efficiency scores for non-economic factors, such as animal health and welfare (Barnes *et al* 2011) and farmer-related social and intellectual factors (Uzmay *et al* 2009).

Several studies have dealt with technical efficiency scores for dairy farms (Lawson *et al* 2004; Stokes *et al* 2007; Uzmay *et al* 2009; Huijps *et al* 2010; Barnes *et al* 2011; Hansson *et al* 2011), but few have focused on animal health and welfare as a factor. Recently, Barnes *et al* (2011) included lameness in dairy cattle as a measure of animal health and welfare into the calculation of technical efficiency using data envelopment analysis. Within a sample of 80 British dairy herds, farms with lameness prevalence below 10% were more efficient than farms with a higher percentage of lame animals.

Benefits from implementing management changes on a farm for mastitis have been analysed by Huijps *et al* (2010) using data envelopment analysis. Percentage improvement in udder health was derived from Monte Carlo expert evaluation analysis. In total, 18 different management practices were analysed, and results showed that four of these measures were the most cost-efficient ones: keeping cows standing after milking, rinsing milking clusters after clinical mastitis cases, using separate cleaning material for each animal, and wearing milkers' gloves. Although wearing milkers' gloves had only small effects on udder health, the very low costs associated with this measure resulted in a high cost-efficiency. In contrast, post-milking teat disinfection showed the highest efficacy concerning udder health but was not identified as a cost-efficient measure (Huijps *et al* 2010).

Hansson *et al* (2011) aimed to identify management practices that were more common on fully efficient Swedish dairy farms. Common management routines that are known to be successful to improving udder health, like post-milking teat disinfection, choice of bedding material or frequency of cleaning stalls, were less important for farm technical efficiency, although they may still have a positive effect on animal health and welfare. On the other hand, management decisions, such as culling cows with high somatic cell count or contacting a veterinary surgeon, were associated with a fully efficient farm (Hansson *et al* 2011). These findings point to a mismatch between what may be viewed best for the animals' health and welfare and for being cost-efficient. However, more expensive options may in some cases be needed to effectively improve welfare and giving advice to farmers based solely on cost-benefit considerations could hamper an improvement in animal health and welfare due to waiving successful interventions for the animals simply because they are less cost-efficient (Bruijnis *et al* 2013).

Non-monetary effects for the farmer

Besides economic benefits, farmers may experience other aspects of improved animal health and welfare as rewarding. Their goals may go beyond maximising economic profit, to include aspects such as job satisfaction (Hogeveen *et al* 2011). Such non-monetary social aspects are difficult to quantify, and so far have not been considered in animal health and welfare planning studies. However, they seem to be important factors for farmers and influence their motivation to implement changes. Such aspects have frequently been self-reported by farmers when analysing their motivation to become involved in animal welfare improvement (Valeeva *et al* 2007; Leach *et al* 2010b). For example, it has been shown that 'internal esteem' and 'taking pleasure in healthy animals on the farm' play a meaningful role in motivating farmers to control mastitis, and are equally as important as monetary factors (Valeeva *et al* 2007). With regard to their motivation to improve lameness, farmers even deemed 'being proud of a healthy herd' more important than the fact that 'lame cows lose money' (Leach *et al* 2010b). Thus, these non-monetary aspects should also be taken into consideration when influencing farmers' action.

Success and risk factors for health and welfare improvement

Awareness of problems

The farmers' awareness of animal health and welfare issues has to be considered in health and welfare planning (Vaarst *et al* 2006; Valeeva *et al* 2007; Jansen *et al* 2009). Different welfare concerns have shown to be unequally perceived by the involved farmers. For example, lameness in dairy cattle is often underestimated (Whay *et al* 2002; Main *et al* 2003; Barker *et al* 2010; Leach *et al* 2010a). Uncertainty and differences in the definition of a lame animal and lack of knowledge and training (Whay *et al* 2002) may be responsible for the misidentification of lameness, as well as the occupation of the farm staff with other work than observation of gait (Leach *et al* 2010a). Similarly, a certain level of lameness prevalence may be considered 'normal' and therefore not questioned further (Whay *et al* 2002; Leach *et al* 2010a; Šárová *et al* 2011). With regard to such inatten-

tional blindness of the farm situation, Gratzer (2011) highlighted the potential of external, independent persons to overcome such barriers in the planning process. Compared with lameness, mastitis incidence is estimated more precisely by the farmers (Whay *et al* 2003). Farmers' estimations of economic losses caused by mastitis are, however, inaccurate as they overrate direct costs such as veterinary assistance but underestimate indirect costs caused by, eg increased replacement rates (Huijps *et al* 2008). Immediate penalties for decreased milk quality due to mastitis cases may be seen as one reason why awareness of mastitis is more pronounced (Whay *et al* 2003). The financial consequences of lameness seem to be less obvious to the farmer (Leach *et al* 2010a). However, with increasing duration of monitoring and advice, Brinkmann and March (2010) observed an improved detection of lame animals by the farmers themselves.

Comprehensiveness of approach

In general, focusing on one single aspect of health and welfare at a time seems to be more promising than comprehensive approaches. Farmers participating in studies that implement comprehensive plans (eg Ivemeyer *et al* 2012) prefer to focus on single but essential areas (Brinkmann & March 2010). In line with this, few farmers addressed welfare issues that contribute to a more comprehensive strategy when given the choice to address one or several areas (Gratzer 2011). Areas such as udder health, lameness, or fertility, were more important to the farm personnel, indicating the greater importance of disease and production-related issues in such comprehensive planning approaches. The farmers were less familiar with welfare-related areas such as human-animal relationship or the incidence of agonistic social behaviours.

Benchmarking

When providing feedback on the farms, too much detail and information can easily lead to losing the overview of the situation (Bonde *et al* 2001), and can furthermore hamper successful welfare improvement. Regarding the benchmarking approach, the participating farmers in a dairy cattle lameness intervention study appreciated the chance for comparison and competition with other farms (Brinkmann & March 2010). This may have increased the awareness of health- and welfare-relevant aspects of lameness, which is essential for any change in farmers' behaviour. Also, for health and welfare planning in organic pig production, Leeb *et al* (2010) underlined the relevance of benchmarking as a positive aspect for the farmer. However, in the context of lameness, UK dairy farmers were not convinced of the usefulness of being compared with other farmers (Leach *et al* 2010b).

Farmer attitudes

Farmers' commitment as regards the actual implementation of recommended measures is a main success factor for welfare improvement (Bell *et al* 2006). For example, improvement in udder health was associated with the rate of implementation of measures (Green *et al* 2007). The reasons for a lack of implementation often remain unclear or are not further discussed (Bell *et al* 2009). However, important properties appear to be the feasibility of implementation on the farms (Sibley 2006) and farm-specificity of interventions (Goeritz *et al* 2007; March *et al* 2007; Kristensen & Enevoldsen 2008).

Farmers that explicitly stated an aim of improving udder health achieved a reduction in BMSCC compared to farmers with other motivations (eg interested in herd health management; Ivemeyer *et al* 2008). Also, Brinkmann and March (2010) showed an improvement in udder and leg health, respectively, when the farms were allocated to the intervention group according to their motivation to actively improve the herd health state. This shows that farmers interested in such an intervention study can benefit from it; however it might not indicate that this approach would work for the average farm. The farmers have to acknowledge the plan as an effective management tool that benefits them and their animals (Hovi *et al* 2004; Bell *et al* 2006; Sibley 2006). The early participation of farmers giving their own perspective in finding practicable solutions is essential for the implementation of these changes, and should not be underestimated (Vaarst *et al* 2002; Hovi *et al* 2004; Vaarst *et al* 2007). For instance, assigning veterinary surgeons to implement a lameness control plan on the farms was not efficient in tackling lameness (Bell *et al* 2009). The veterinarians received the results of the assessment of the farms and were asked to develop lameness control plans. However, only after this stage were farmers involved in the planning process, which both veterinarians and farmers had to agree upon and this may have led to a low concordance with the plans.

External expertise

The latter example does not exclude the importance of involving external expertise, eg from agricultural advisors, nutritionists or veterinarians. According to Kristensen and Enevoldsen (2008), Danish dairy farmers were explicitly interested in involving experienced veterinarians. Also, Derks *et al* (2013) underlined the importance of high quality veterinarian advice and mutual trust in the context of veterinary herd health management. To meet this demand, veterinarians have to be able to combine classical veterinary disciplines with management and business to create a whole farm management plan.

Continuous review of the on-farm plan

A frequent review of the health and welfare plan is desired, but in practice not always achieved. Among 61 UK dairy farms, 87% had some form of written plan but only half of the farmers had reviewed their plans within the last 12 months (Bell *et al* 2006). It has been further shown that the frequency of coaching has an influence on how well the recommended measures will be put into practice (Green *et al* 2007; Ivemeyer *et al* 2009; Brinkmann & March 2010). Lameness reduction, as shown by Brinkmann and March (2010), relied to a certain extent on frequent advisory meetings on the farms especially in the first year after implementing the plan (up to four times). This allowed immediate adaptation of the improvement measures as necessary.

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Baseline level of welfare issues

Farms with comparatively low health and welfare status show a higher potential for improvement (Green *et al* 2007; Ivemeyer *et al* 2009). Indeed, organic dairy farms in Denmark with high incidence of mastitis treatments considerably reduced the use of treatments, whereas initially good farms were less able to further improve their udder health situation (Bennedsgaard *et al* 2010). Similarly, the rate of improvement in lameness was positively associated with the initial prevalence (Brinkmann & March 2010; Main *et al* 2012).

Although this has never been further investigated, the fact that farms with an already high health state are less likely to improve may be attributed to two reasons. First, they may already be good at detecting problems and therefore retain a low incidence rate. Second, depending on the parameter, a ceiling effect may occur making health improvement beyond a certain point less likely.

Time-frame for effective interventions

Considering the variety of welfare areas and their multidimensional backgrounds, interventions are likely to require different time-periods in order to successfully improve health and welfare. The limited number of studies provides a heterogeneous picture but indicates that longer monitoring periods are more likely to reveal significant changes. Improvements in mastitis incidence have been found after one year (Green *et al* 2007), but Ivemeyer *et al* (2009) reported only trends for improvement of udder health after this period. However, two years advice on mastitis prevention resulted in significant improvements, for example, with regard to treatment incidence (Ivemeyer *et al* 2008). Long-term studies exceeding a two-year time-span are uncommon. Both Brinkmann and March (2010) and Main *et al* (2012) found a significant improvement in lameness after one year but improvement continued through the following three years. Changes in daily management and routine procedures might be easier and more quickly implemented whereas more fundamental changes will require a longer time-period (Ivemeyer *et al* 2009). Longer monitoring periods offer more time for the farmer to implement the proposed measures and, on the other hand, considerable improvements such as major changes in housing system or breed, require longer periods to become effective (Brinkmann & March 2010). For instance, adjusting the feed ration that involves adaptation of forage production will take at least one growing season to be noticeable. Similarly, the animals' response to, eg measures focusing on reproductive disorders, may require time. Improvements may also only become apparent at herd level when previously affected animals have left the herd since, for example, animals having suffered from lameness are more likely to recur (Hirst *et al* 2002; Dippel *et al* 2009).

Animal welfare implications

Innovative and effective approaches to improve dairy cattle welfare are urgently needed. Structured planning as outlined in this review seems to be a promising way to promote health and welfare in dairy cattle. While improvements have been achieved mainly with respect to lameness and mastitis so far, more comprehensive approaches that go beyond health-related aspects of animal welfare appear important but have been rarely studied. Similarly, information on economic aspects of health and welfare planning is scarce, but may contribute to improvement efforts in future. The inclusion of examination of non-monetary benefits to farmers also appears to be promising in this context.

Conclusion

Targeted animal health and welfare planning has been shown to be a promising approach for enhancing udder health. However, efforts to reduce lameness are not always successful. Studies on more comprehensive approaches addressing welfare in a wider sense are rare and the results less convincing. Further research regarding planning strategies should focus therefore on welfare aspects that go beyond the most important production diseases. While the costs of impaired health and welfare have been analysed, studies on the overall economic implications of improving health and welfare are scarce. Moreover, investigation of non-monetary benefits has frequently been demanded, but rarely been carried out. Successful planning processes are based on the participation of all involved persons and on mutual trust. Furthermore, appropriate and farm-specific measures in management and housing, a high compliance with those measures, continuous review and prompt adaptation appear to be decisive in ensuring plans are effective.

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