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SCIENTIFIC OPINION

Scientific Opinion on the use of animal-based measures to assess welfare of dairy cows[1]

EFSA Panel on Animal Health and Welfare (AHAW)[2, 3]

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ABSTRACT

Animal-based measures, identified on the basis of scientific evidence, can be effectively used in the evaluation of the welfare of dairy cattle on farm in relation to laws, codes of practice, quality assurance schemes and management. Some of these measures are also appropriate for ante-mortem inspection and there are additional post-mortem animal-based measures which can be taken at the slaughterhouse. The validity and reliability of the measures should be known. There do not seem to be any animal welfare issues that can not be addressed using animal-based measures, but there may be practical constraints that make it difficult to use some animal-based measures or which make the use of non-animal-based measures preferable in some situations. Non-animal-based measures can be used when the association between them and the welfare outcome is strong and when they are more efficient than animal-based measures as a means to safeguard welfare. Some animal-based measures are early indicators and can be used to predict those animals at risk of poor welfare. Others can only be used for welfare assessment if collected over a long period, in which case they are best taken from historical records or recording systems. For an overall classification of welfare, a wide range of measures is needed. However, it is unnecessary to use all animal-based measures on every occasion. The choice of animal-based measures will depend upon the specific objectives of the assessment. The full list is comparable to a 'toolbox', from which the appropriate range of measures can be selected. The Welfare Quality® protocol provides information on the majority of the welfare outcomes of the main hazards identified in the EFSA Scientific Opinions but not those where time limitation prevents it. The extent to which short-term management can prevent the negative effects of hazards arising from genetic selection, and of most housing-related problems, is extremely limited. Herd monitoring and surveillance programmes should be implemented within the dairy industry using a range of appropriate animal-based measures in order to document welfare changes over time. There should be both initial and ongoing training of assessors to ensure valid and reliable welfare measurement.

KEY WORDS

dairy cows welfare, animal-based measure, welfare assessment

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SUMMARY

Following a request from the European Commission, the Panel on Animal Health and Welfare was asked to deliver a Scientific Opinion on the use of animal-based measures to assess the welfare of dairy cows. Although there is a recently completed EFSA Scientific Opinion on the overall effects of farming systems on dairy cow welfare and disease, there are currently no specific rules at the European Union level for the welfare of dairy cows. This Opinion is the first of a series of Scientific Opinions that relate to two key areas in the European Community Action Plan on the Welfare of Animals, the first of which is upgrading existing minimum standards for animal protection and welfare, and the second is introducing standardised animal welfare indicators.

Animal-based measures have been used by scientists for many years to measure the responses of animals as indicators of their welfare. In contrast to these animal-based measures, rules related to animal protection have usually focused on measures of the environment (resources) or management (practices) (i.e. on risk factors rather than on their consequences for the animal). A European Union (EU) financed project, called Welfare Quality®, has been influential in developing a standardised system for the assessment of animal welfare on farms. In line with the European Commission's intention to adopt a more outcome-based approach to animal welfare, the Welfare Quality® project focused on animal-based measures and produced a welfare assessment protocol for several species, including dairy cattle.

The concepts of animal welfare used in the Welfare Quality® project and the EFSA Scientific Opinions overlap considerably, confirming general agreement in the scientific community related to the definition of animal welfare. However, the challenge in this Opinion has been to merge the risk assessment approach of the EFSA Scientific Opinion on the welfare of dairy cattle with the welfare assessment approach of Welfare Quality®, as well as other related research projects on dairy cattle welfare.

In most cases, the responses of an animal to features of its environment have little impact on its welfare. However, sometimes the response is of such magnitude that it indicates the animal has difficulty coping, or did not cope, and its welfare is reduced as a consequence. Sometimes these responses are the outcome of many days, weeks or months of minor responses and hence the terms 'welfare outcome indicator' or simply 'outcomes' are used in animal welfare science. The EFSA Scientific Opinion on dairy cow welfare focused on identifying the hazards that lead to these negative welfare outcomes and then making recommendations to reduce or eliminate them. The Welfare Quality® project, on the other hand, focused on measuring the magnitude of the outcomes, facilitating an assessment of dairy cow welfare irrespective of housing system and management.

Despite these different starting points, it is concluded that the Welfare Quality® dairy cow protocol covers the majority of the main hazards identified in the EFSA Scientific Opinion and that animal-based measures are necessary to determine whether or not the improvements in welfare intended by the recommendations in the Opinion are achieved. However, it was noted that there is a lack of specificity in some of the hazards (e.g. cubicle design), which means that there are several outcomes that could be measured, and also, sometimes, there is a lack of specificity in an animal-based measure (e.g. body condition score), which means a welfare outcome could have one or several causes. Thus, the links between hazards (resources and management) and their welfare consequences (using animal-based outcome measures as indicators) is far from simple and a limitation of the approach used in this Opinion has been the difficulty in visualising this complex network of direct and indirect links. Nevertheless, a 'toolbox' of valid and reliable animal-based measures is envisaged, from which the most appropriate 'tool' or combination of tools can be selected. The selection will depend on what welfare outcomes are to be assessed and the reason for wanting to assess them (e.g. whether part of a management/breeding strategy or to enforce legislation). Several animal-based measures listed in this Opinion are already fully developed, although they are not widely used in commercial practice (e.g. gait scoring, getting up and lying down behaviour), and many more animal-based measures are in use, but not in a welfare assessment context (e.g. somatic cell count, number of completed lactations).

Assuming that data from the standardised use of some of these measures (in a variety of real life situations) could be collected on a regular basis, the available data the could be analysed to describe these complex associations. This would continually improve the selection process of appropriate animal-based measures for different contexts and also pave the way for a move towards quantitative risk assessment of animal welfare.

Until then, there are several ways in which animal-based measures can be, and are being, used to assess the welfare of dairy cows. Many of the animal-based measures that are referred to in this Opinion are related directly or indirectly to the health, production and behaviour of cows. Although most often used to identify animals that already have poor welfare, some could also be used to identify animals whose welfare is decreasing, so that changes can be made before the individual is adversely affected (e.g. raised somatic cell count, increased lying time). Thus, in monitoring and surveillance systems, some animal-based measures may be useful not only because they can indicate current welfare problems in the herd, but because they can also serve as a tool for early detection of findings that may indicate a potential future negative situation. In the writing of this Opinion, no animal welfare issue was identified that could not be addressed using animal-based measures, but several situations were identified where an alternative measure was used in practice. The most common reason was that there was a resource-based measure that was easier to record and almost as reliable. Another reason was that the animal-based measure was too time consuming to collect or required specific skills or analysis, although several of these may soon become feasible under commercial farming conditions using automatic recording techniques.

In some cases, such as with changes in breeding goals, it may take a long time for an improvement in animal-based measures to be noted at the farm level. More specifically, a conclusion in this Opinion is that negative consequences of factors such as genetics and housing, often cannot be easily prevented through management. Nutritional- and management-related hazards, on the other hand, are suggested as easier to manage in the short-term, assuming that the person involved is willing and able to make the change.

Recommendations in the EFSA Scientific Opinion on dairy cow welfare were formulated around hazards and these, by definition, relate to the animal's environment and how it is managed. Controlling whether or not a recommendation is fulfilled is therefore most logically carried out using the appropriate resource- or management-based measure. However, the likelihood of a feature in the environment becoming a hazard depends on the characteristics of the animal it is acting upon. Animals differ in aspects such as their genetics or age, and thus may experience and respond to hazards in different ways. Indeed, this is the reason why animal-based measures, describing the consequences of the animal's attempts to cope with its environment, are the preferred indicators of animal welfare. Future EFSA recommendations, although based on risk assessments, should whenever possible be formulated in such a way that it is clear which animal-based measure is to be used for control in order to ensure that the intention of the recommendation for improved animal welfare is achieved.

Although referred to as animal-based, as stated previously, the aim is to collect information about the response of the animal. Data can therefore be collected on-farm by either observation or inspection of the animal, or from other sources, such as milk or meat inspection, disease reporting systems, production records and so on. Furthermore, although welfare is a characteristic of the individual animal, many of the animal-based measures are in fact reported at the herd level (e.g. prevalence of lameness). An expanded list of potential animal-based measures is provided in this Opinion. Benchmarking is increasingly used to track changes within the same farm over time or, more often, to compare farms. When the same animal-based measure is compared between farms with similar housing systems and management practices, it facilitates the identification of those farms that are outside the normal range of variation and this information also becomes relevant to the assessment of dairy cow welfare.

In summary, animal-based measures are likely to highlight the most important and urgent welfare problems, and so focus priorities for remedial action. Resource- and management-based measures are more likely to highlight the potential risk of reduced welfare in the future and help identify the reasons underlying current animal welfare problems. Thus, both animal-based and non-animal-based measures are needed in a control or assessment protocol. There is a wide range of potential areas for the implementation of protocols for the assessment of dairy cow welfare and the most appropriate balance of animal-, resource- and management-based measures will depend on the specific objectives of the assessment. Animal-based measures that cover several of the hazards and reflect several of the poor welfare outcomes identified in this report include measures of lameness, leg injuries, mastitis, colliding with equipment when getting up and lying down, and poor body condition. There are currently several methods for taking animal-based measures within each of these areas. For comparisons of animal-based measures and for benchmarking it would be necessary to select one standardised method. This method should be demonstrated to be fit for the purpose (i.e. shown to be valid, reliable and feasible). The thresholds below which the level of welfare indicated by the animal-based measure is deemed unacceptable or is a call for action will depend on the aim of the welfare assessment.

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BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

Request for a Scientific Opinion concerning the use of animal-based measures to assess the welfare of dairy cows.

Council Directive 98/58/EC[4] concerning the protection of animals kept for farming purposes, lays down minimum standards for the protection of animals bred or kept for farming purposes, including cattle, although no specific rules are laid down at the European Community level for dairy cows. Two main areas of action of the Community Action Plan on the Protection and Welfare of Animals 2006-2010[5] are "upgrading existing minimum standards for animal protection and welfare..." and "introducing standardised animal welfare indicators in order to class the hierarchy of welfare standards applied...".

One of the main outcomes of the EU-funded Welfare Quality® project is the science-based methodology for assessing animal welfare and a standardised way of integrating this information to assign farms to one of four categories (from poor to excellent animal welfare) regarding welfare. Procedures and requirements for the assessment of welfare in cattle, pigs and poultry are presented in the assessment protocols. The use of animal-based measures to assess animal welfare is relatively new; but diverse research projects focus on these now; such measures are also considered in various assessment schemes. Previous assessments relied mainly on resource-based parameters. Animal-based measures aim to directly measure the actual welfare status of the animal and thus include the effect of resource as well as management factors.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

The Commission therefore considers it opportune to request EFSA as a first step to give an independent view on the animal based welfare measures for dairy cows.

- Identify how animal-based measures could be used to ensure the fulfilment of the recommendations of the EFSA Scientific Opinions on the welfare of dairy cows.
- Furthermore, how the assessment protocols suggested by the Welfare Quality project cover the main hazards identified in EFSA Scientific Opinions and *vice-versa* for an overall classification of the welfare situation.
- Identify which relevant animal welfare issues cannot be assessed using animal-based measures for dairy cows and what kind of alternative solutions are available to improve the situation.
- List main factors in the various husbandry systems which have been scientifically proven to have negative effects on the welfare of dairy cows and to what extent these negative effects can be or not prevented through management.

The assessment should be based and linked on/to the risk assessment of the previous EFSA Scientific Opinions.

[4]Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes. OJ L 221, 8.8.98, p23-27.

[5]Communication from the Commission to the European Parliament and the Council of 23 January 2006 on a Community Action Plan on the Protection and Welfare of animals 2006-2010. OJ C 49 of 28.02.2006

ASSESSMENT

1. Introduction

The European Community Action Plan on the Protection and Welfare of Animals refers to the introduction of standardised animal welfare indicators. This Opinion is an overview of the current and potential future use of animal-based measures to assess the welfare of dairy cows by farmers, veterinarians and other inspectors, checking on compliance with laws or standards, and is divided into three main sections. The first section deals with concepts related to the assessment of welfare using animal-based measures, including the link between animal-based measures and welfare outcome indicators. The second section discusses the four terms of reference outlined in the mandate. A third section addresses ways in which data and information on the links between the factors affecting welfare and the measures used to assess welfare can best be merged to facilitate further developments in welfare assessment.

1.1. The EFSA Scientific Opinion on the welfare of dairy cows and the Welfare Quality® research project

In 2006, EFSA was requested to provide a Scientific Opinion on the welfare of dairy cows, with the specific objective to consider whether current farming and husbandry systems fulfil the needs of, and lead to, good welfare of dairy cows from pathological, technical, physiological and behavioural points of view. This resulted in: a scientific report (EFSA 2009a), an overall Scientific Opinion (EFSA, 2009b) and four Scientific Opinions based on risk assessments dealing with four broad categories of welfare outcomes: (i) metabolic and reproductive disorders (EFSA, 2009c), (ii) udder disorders (EFSA, 2009d), (iii) leg and locomotion problems (EFSA, 2009e), and (iv) behavioural disorders, fear and pain (EFSA, 2009f). In the risk assessments, factors that may contribute to poor cattle welfare (hazards) were identified and the risks were assessed separately for tie-stalls, cubicle houses, straw yards and pasture. One recommendation from the overall Scientific Opinion (EFSA, 2009b) was that the body of research on dairy cattle welfare should be incorporated into codes of practice and monitoring protocols that address potential hazards and incorporate animal-based measures of welfare outcomes.

Welfare is defined according to Broom (1986) as follows: "the welfare of an individual is its state as regards its attempts to cope with its environment". This concept was followed by the World Organisation of Animal Health (OIE) that defines animal welfare as: (i) how well an animal is coping with the conditions in which it lives, (ii) an animal having good welfare if, as indicated by scientific evidence, it is healthy, comfortable, well nourished, safe, able to express key aspects of behaviour, and if it is not suffering from unpleasant states, such as pain, fear and distress, and (iii) good animal welfare requiring disease prevention and veterinary treatment for illness and injuries, appropriate shelter, management, nutrition, humane handling and humane slaughter/killing (OIE, 2011). While the term 'animal welfare' refers to the state of an individual animal, in practical circumstances these individual measurements are used to assess the mean welfare in a group or herd. The EFSA Opinion was based on a multidimensional concept of welfare that included both the physical health and the emotional state of the animal.

Welfare Quality® is the acronym for an EU project whose overall aims were to develop a standardised methodology for the assessment of animal welfare, practical strategies/measures to improve animal welfare, and a standardised methodology to translate animal welfare assessments into easily understandable product information (Blokhuis et al., 2003). The project differed from the EFSA Opinions in that it did not aim to identify risk factors that were associated with good or poor welfare. Rather, the project focused primarily on animal-based indicators that could be monitored and used during inspection to assess current levels of welfare (Keeling, 2009). Welfare Quality® proposed the four welfare principles, good feeding, good housing, good health, and appropriate behaviour, which

were linked to 12 criteria that result in good welfare (Blokhuis et al., 2010). The objectives of the four principles have some similarities to the Five Freedoms (FAWC, 2009) and the OIE definition of animal welfare (OIE, 2011) and so can be considered as a useful guideline for achieving good welfare (Rushen et al., 2011). The 12 Welfare Quality® criteria include: absence of prolonged hunger and thirst, comfort in relation to resting, thermal conditions and ease of movement, absence of injuries, disease and pain, expression of social and other behaviour, good human-animal relationship and positive emotional state. These welfare criteria were in turn linked, in the detailed Welfare Quality® dairy cattle protocol, to a series of welfare measures, such as those related to body condition, lameness, avoidance distance and presence of tethering or access to pasture (Forkman and Keeling, 2009; Welfare Quality®, 2009).

The measures of welfare used in the Welfare Quality® dairy cattle protocol have links to the four broad categories of welfare outcomes for dairy cows considered in the 2009 EFSA Scientific Opinion. Thus, in general, the concepts of animal welfare used by the Welfare Quality® project and the EFSA Opinion overlap considerably. The main exception being that Welfare Quality® included more signs of good welfare (i.e. positive emotional state) than the EFSA Opinion. The Welfare Quality® project proposed that, since animal welfare is a multidimensional concept, all criteria are important and that good welfare in one dimension of welfare (e.g. the possibility to perform appropriate behaviour) does not compensate, or at best only marginally compensates, for poorer welfare in another (e.g. health), or *vice versa*. There have been further developments in the terminology related to risk assessment since the 2009 dairy cow welfare Opinion, and in this current Opinion the new terminology is used according to the Guidance on Risk Assessment for Animal Welfare (EFSA, 2012a).

1.2. Concepts

In the previous EFSA Scientific Opinion on the welfare of dairy cows (EFSA, 2009b, c, d, e, f), the word 'hazard' is used to mean something that increases the risk of impaired welfare and, therefore, it is also used in the mandate for this Opinion. However, work in EFSA is increasingly moving towards assessment of both risks and benefits and it is recommended that the word 'factor' is used instead of hazard, to reflect this. The term 'factor' means any aspect of the environment or the animal, alterations in which may have the potential to improve or impair the welfare of animals. In this Opinion, the word 'factor' can be considered as synonymous with 'hazard' when addressing factors that have the potential only to impair welfare. There are also slight differences in terminology related to animal welfare in the EFSA dairy cattle Opinions and in the Welfare Quality® publications, although the underlying concepts are the same. A glossary at the end of this Opinion lists all specific terms used in the Opinion.

The factors that affect an animal's welfare (Figure 1) include the resources available to the animal (which are assessed with resource-based measures), such as space allocation, housing facilities and bedding material, and the management practices of the farm (which are assessed with management-based measures), such as how often the animals are milked, whether or not analgesics are used, breeding strategies, etc.

Depending on its characteristics (breed, sex, age, etc.) the animal will respond to these inputs, and the animal's responses are assessed using animal-based measures. In risk assessment terminology, these responses are the 'consequences' of exposure to the 'factors'.

Figure 1: An overview of the terminology

In most cases, the responses of the animal are adaptive, with little impact on its welfare, which indicates that the animal can cope quite easily with the factors to which it is exposed. However, sometimes, the response is of such magnitude that it indicates the animal has had difficulty in coping, or was not able to cope, with these factors and, consequently, the animal's welfare was impaired. In other cases, it is an effect on the animal rather than a response, for example, an injury. Sometimes a major response can be the outcome of many days, weeks or months of more minor responses or effects, such as those that might follow chronic stress or prolonged lack of appropriate nutrient levels in the feed. The terms 'welfare outcome indicator' and even simply 'outcomes' are starting to be used in animal welfare science for these major changes in animal-based measures that clearly indicate welfare has been affected (see the Glossary for definitions of animal-based measures and welfare outcome indicators). There is a continuum between these responses, which indicate a clear increase or decrease in welfare, and more minor responses. Consequently, it may be difficult to set a threshold indicating whether or not a response is a sign that the animal is having difficulties coping with its environment.

Much of the research relevant to this Opinion addresses the need to identify valid and robust outcome-based indicators of dairy cow welfare and, wherever possible, allocate reliable scales to be used when scoring responses (e.g. loss of body condition, locomotor disorders). The overall welfare of an animal will be determined by the diversity of the responses, as well as by the magnitude of the responses and their consequences. However, the decision as to what is, and what is not, acceptable is a matter of ethics and can be expected to vary according to human values and attitudes towards animal welfare. Our aim is to ensure that ethical decisions concerning the acceptability of husbandry inputs (resources and management) and about welfare outcomes are based on sound evidence.

Many of the animal-based measures discussed in this Opinion are based on the health, production and behaviour of dairy cattle, as the aim of animal-based measures is to collect information about the response of and effects on the animal. Therefore, data can be collected either by direct observation or inspection of the animal or indirectly from the effects of the animal's response on the environment (e.g. loose faeces on the floor reflecting diarrhoea). Data can also be collected through other sources, such as disease reporting systems (surveillance), milk production records, meat inspection, and so on.

1.3. Essential attributes of animal-based measures

As with diagnostic tests for disease, when using animal-based measures to assess welfare, quality criteria, assessment protocols and precise terms (see the Glossary) should be used. In this report, the word 'measure' is used to mean a form of evaluation rather than an intervention intended to deal with a problem. A 'measurement' is the result of this evaluation (e.g. size and depth of wounds, percentage of lame animals).

Measuring approaches generally have to be fit for the intended purpose, that is to say they need to be valid (accurate and precise), reliable (repeatable, reproducible and robust) and feasible (practical, economic, etc.). In the context of diagnostic tests for animal diseases, specific validation protocols have been established for estimating key performance parameters, such as diagnostic sensitivity and specificity, against a defined reference standard. This requires an independent and correct test system to define disease in terms of an appropriate selection of measurable changes from reference points for good health (e.g. normal body temperature). The challenge for animal welfare assessors is to provide a comparably valid series of reference points from which to measure departures from good welfare. Animal-based measures, as indicators of animal welfare, are increasingly being tested for their 'fitness for purpose' according to these essential attributes.

Welfare is a characteristic of the individual at a stated time, and most animal-based measures are taken on individual animals. However, individual animal data can be aggregated to a herd/flock or even population level, expressed using summary measures, such as proportions or means, and interpreted against predefined threshold values. In cases where measurements are collected from a sample of animals, it is essential that the sample be unbiased and representative in terms of potential influencing characteristics, such as, for example, parity, stage of lactation, body size, etc. This will depend upon the epidemiological unit of analysis.

2. Addressing the terms of reference

There are four terms of reference (ToRs) in this mandate and each is addressed in a separate section of the report, although there are links between them and information generated when answering one ToR is also used to answer another. To address ToR 1, a list of all recommendations from the EFSA Scientific Opinion was made and beside each recommendation any animal-based measure considered useful to measure the factor underlying that recommendation was listed. A special note was made if the measure was proposed in the Welfare Quality® protocol. If no animal-based measure had been proposed previously in the literature and none was considered obtainable from animal records, an attempt was made to propose a non-animal-based (resource- or management-based) measure. To address ToR 2, another table was developed, this time using the most important factors (hazards) identified in the four risk assessments in the 2009 EFSA Scientific Opinion on the welfare of dairy cows (EFSA, 2009c, d, e, f). These factors were ranked according to the risk estimate scores allocated to them by the experts in the dairy cow Working Group and they were linked to the lists of animal-based measures identified when addressing ToR 1. In this way, the links between factors (hazards) and animal-based measures, including those proposed in the Welfare Quality® research project could be identified. Based on the available information in the source documents and the large number of factor-outcome and outcome-indicator links in the context of this mandate it was not possible to explore the diagnostic quality fully (i.e. validity, reliability and feasibility) of selected animal-based measures towards specific welfare outcomes – as is carried out in the validation of diagnostic tests.

Using the tables, it was found that some of the factors that have impacts on animal welfare, and some of the recommendations in the EFSA Opinion, did not have any corresponding animal-based measures in the Welfare Quality® protocols or in the general animal welfare literature. An attempt was made to group these 'gaps' in order to identify any common features. In this way, it was possible to address ToR 3 in the mandate, which asked whether there are animal welfare issues that cannot be assessed using animal-based measures and what kind of alternative solutions are available to improve the situation.

ToR 4 asked for a list of factors in husbandry systems that have been shown to have a negative effect on the welfare of dairy cows and the extent to which such negative effects can be prevented by management. A Delphi approach was used to answer this ToR. Using the table developed to answer ToR 2 (listing the main factors, often hazards, identified in the EFSA Scientific Opinion affecting dairy cattle welfare; EFSA, 2009c, d, e, f), experts in the Working Group were asked to score on a scale from 1-5 the extent to which they thought the negative effects could be prevented by management. Following standard Delphi methodology, this scoring was initially carried out independently. Experts then received the average score from the group of experts, and had a chance to modify their answer. Only in the final phase, and only for the factors where there was a difference in scores given by experts, were the results discussed.

As a final stage in addressing the four different ToRs in this Opinion, experts from outside the Working Group with expertise in dairy cow welfare were invited to review critically the approach taken by the Working Group. Any new insights gained from this consultation were added to the report. A major challenge in this work has been to take the EFSA (risk assessment) approach and the Welfare Quality® (welfare assessment) approach and combine them into a single (operational) approach.

In addition, two procurements were carried out. The first was a review of methodologies applicable to the validation of animal-based indicators of welfare, and the second addressed the relationship between animal welfare hazards and animal-based measures.

A public consultation was conducted by EFSA. Comments received and additional measures were incorporated into this Scientific Opinion when the Working Group considered their scientific basis to be valid and robust (EFSA, 2012b).

2.1. How animal-based measures could be used to ensure the fulfilment of the recommendations of the EFSA Scientific Opinions on the welfare of dairy cows (ToR 1)

Firstly, the fact that a recommendation from the EFSA Scientific Opinion (EFSA, 2009b) is fulfilled does not necessarily mean that the intended welfare improvement for the animal is achieved. Most recommendations in the Scientific Opinion on the welfare of dairy cows are phrased in terms of the specific resources to be supplied to the animals or the types or quality of management to be used. Fulfilment of these recommendations is most easily achieved by using resource- or management-based measures. For example, one of the recommendations from the EFSA Scientific Opinion states that 'cubicle width should be at least 1.8 times cow hip width' (Recommendation 23 in Appendix 1). Thus, the recommendation is fulfilled if the farm has cubicles of this width. Since having cubicles of this width decreases several risks related to teat injuries, cows lying down outside of the cubicles and difficulty in changing position, an alternative way to assess whether or not these intended welfare improvements are actually achieved would be by observing the incidence of teat injuries, cows lying in passageways, etc. A better formulation of a recommendation therefore is the one that states 'where cubicles are used, they should be wide enough, in relation to the size of the cows, to minimise any movement difficulties or teat trampling' (Recommendation 21 in Appendix 1), which specifies an animal-based measure (trampled teats) to be recorded to determine whether or not the recommendation has been fulfilled. Other recommendations are very broad, such as that 'dry cows should be kept in good conditions'. These do not need to be the same as those used for cows during the milking period and can include 'the possibility for sufficient movement to prevent problems listed elsewhere' (Recommendation 36 in Appendix 1), which is unspecific and therefore difficult to determine whether or not it is fulfilled. However, if there is strong evidence that a specific resource or management factor is very likely to lead to a negative welfare consequence of high magnitude, then it would be appropriate to consider removal of that factor (prevention is better than treatment).

Secondly, as stated earlier, the relationship between the factor and the welfare consequence (see Figure 1) is often far from clear. For example, another recommendation is that 'the cleaning of udders should take full account of the risk of transmission of pathogens' (Recommendation 58 in Appendix 1). This recommendation is intended to reduce the incidence of contagious mastitis. However, even if

cleaning the udders is thorough, cows may still develop mastitis for other reasons. Consequently, if mastitis is not monitored, the desired outcome cannot be confirmed even if the recommendation has been fulfilled.

Thirdly, for some factors affecting welfare, the animal-based measure is clearly more useful as it will give direct information about poor welfare that could not be obtained from any other measure. Nevertheless, animal-based measures are sometimes relevant to several recommendations. For example, a failure to follow a number of recommendations would be expected to lead to an increased prevalence of lameness. What this means is that if a farm has a low prevalence of lameness, then it must be assumed that the expected welfare outcome of all these recommendations is being achieved. However, if a high prevalence of lameness were found on a farm, then we would not know which particular recommendation was not being followed. This could only be discovered by using other animal-based measures or by using resource- or management-based measures to identify the cause of the high prevalence of lameness.

In summary, the exact formulation of the recommendation determines what type of measure (animal-, resource- or management-based) should be used to ensure the fulfilment of the recommendation, and this should be considered when formulating recommendations in future.

2.1.1. Procedures used to link measures to recommendations

Although implementation is a central issue to the question in this mandate, we have refrained from being specific about how animal-based measures are implemented or where a threshold between acceptable and unacceptable for a particular measure should be set. Instead the focus has been on which measures may be implemented and what aspects should be considered when deciding whether or not to implement them. Some of these points were already dealt with in the section on essential attributes of animal-based measures (see Section 1.3).

Each of the 105 recommendations considered to be of importance in the EFSA Scientific Opinion on the welfare of dairy cows (EFSA, 2009b) was considered in turn to determine measures (animal-based and non-animal-based; see the Glossary) that would be appropriate to evaluate whether or not the recommendation is being fulfilled, and so leading to better welfare on the farm (Appendix 1). This was initially carried out by a smaller group of experts and then discussed and agreed upon by the Working Group and invited experts. In compiling the list, measures described by Welfare Quality® were associated with the EFSA recommendations, where this was possible. However, it should be noted that this allocation of potential animal-based and non-animal-based measures was undertaken for all EFSA recommendations, irrespective of how the recommendation was formulated (see Section 2.1). The validity, reliability and feasibility of these measures were based on analysis of the scientific evidence, although this did not include a formal, systematic and targeted literature review.

Efforts have been made to propose measures that can be recorded by a veterinary or other inspector on-farm. . However, many of these measures are also appropriate for ante-mortem or post-mortem inspection of the animal at the slaughterhouse.

To give a better overview for the purposes of this Opinion, the large table in Appendix 1, with the 105 recommendations, was sub-divided into several smaller tables reflecting topics addressed in the EFSA Scientific Opinion. These topics are based on risk assessments of the impacts of hazards associated with housing, nutrition and feeding, management and genetic selection on udder problems, leg and locomotory problems, metabolic and reproductive problems, and behavioural, fear and pain problems (EFSA, 2009c, d, e, f). Each table (Tables 1-7) presents the recommendations related to the topic, as well as the potential animal-based and non-animal-based measures. As the focus of this ToR is animal-based measures, only some commonly used non-animal-based measures have been included in the tables. After each table there is a brief discussion to explain, by example, how selections of measures can be combined to provide an assessment of welfare outcomes. The measures identified in these tables (animal-based and non-animal-based) are described in broad terms (e.g. fertility records,

metabolic profiles, feeding behaviour) to indicate which types of observation or measure should be selected to address the specific objective (i.e. the recommendation).

In most cases, the animal-based measures are made on a sample of individual animals and interpreted at the farm or group level (e.g. percentage of animals with hock lesions). However, it was not the intention, nor was it possible within these tables, to describe how the individual observations and measures should be made or how they should be interpreted in the assessment of welfare outcomes, since this will depend on the purpose of the assessment. The amount of published scientific evidence and sound clinical practice underpinning the methodology for recording and interpreting these indicators is very large, and, in most cases, it would be inappropriate to describe measures relating to broad categories, such as fertility, on the basis of individual scientific communications. For this reason, Appendix 2 presents a comprehensive list of all animal-based measures referred to in Appendix 1 and, therefore, in this report. The list can be regarded as a 'toolbox' from which potential measures can be selected. In most cases, directions for those seeking further details of methodology and interpretation can be obtained in the first instance from comprehensive review publications (Rushen et al., 2008; EFSA, 2009a; Welfare Quality®, 2009). Original communications are quoted when they provide a self-sufficient account of what the measure is, as well as the methodology and interpretation. Some, but not all, animal-based measures have already been tested for validity (accuracy and precision), reliability (repeatability, reproducibility and robustness) and feasibility (practicality and cost). It is recommended that animal-based measures are evaluated on these essential attributes before being added to the toolbox and before being used in practice to assess the welfare of dairy cows, so that informed decisions can be taken on their use in different contexts.

The animal-based measures in Appendix 2 were ordered according to how often they were named in Appendix 1 with a view to identifying animal-based measures that were appropriate for the largest number of different recommendations. When this was carried out, the top five animal-based measures to determine the fulfilment of an EFSA recommendation were measures of 'lameness', 'hock, knee and skin lesions and swelling', 'colliding with equipment when standing or lying', 'teat injuries' and 'evidence of mastitis'. The frequency with which an animal-based measure is mentioned in the tables does not necessarily indicate the extent to which the measure is fit for purpose, according to the attributes named above, or how important this particular welfare outcome is to the animal. However, it gives information to those selecting animal-based measures from the 'toolbox' and may help in identification of those farms with problems.

Table 1: Abbreviated list of recommendations related to the provision of FOOD AND WATER, as presented in the EFSA Scientific Opinion on the welfare of dairy cows (EFSA, 2009b), together with a list of potential animal- and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The measures identified in this table are sometimes described in broad terms to cover several more specific measures. The complete text of the recommendation(s) is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See the Glossary for definitions of the terms animal-based and non-animal-based.

Recommendations (EFSA, 2009b)	Animal-based measures	Non-animal-based measures
All dairy cattle should be fed a diet that provides sufficient energy, nutrients and dietary fibre to meet the metabolic requirements in a way that is consistent with digestion (10)	Measure of nutritional status Metabolic profile (e.g. βOHB) Rumen status Faeces consistency Milk composition (e.g. fat/protein) Fertility records Laminitis Measures of feed intake Incidence of milk fever Incidence of ketosis	Diet composition Feeding strategy
Feeding systems should allow every cow to meet its needs for quantity and quality of feed. Concentrate feeding facilities should be adequately maintained and diets carefully balanced to maintain optimal rumen fermentation and to minimise negative energy balance (11, 18)	Measure of nutritional status Metabolic profile (e.g. βOHB) Rumen status Faeces consistency Milk composition (e.g. fat/protein) Fertility records Laminitis Measures of feed intake Neck lesions Behaviour at feeding time	Inspection of feeders and feed barriers Feeding strategy Number of feeding places per animal
When diet is changed there should be carefully controlled transition feeding. Feeding and management of the dry cow should be designed to prevent metabolic disorders such as ketosis and parturient paresis (milk fever) (10, 19)	Measure of nutritional status Metabolic profile (e.g. βOHB) Rumen status Faeces consistency Milk composition (e.g. fat/protein) Fertility records Laminitis Measures of feed intake Incidence of milk fever Incidence of ketosis	Diet composition Feeding strategy Feed space and availability (feeding time and frequency)
Dairy cows should be presented with continuous access to good quality drinking water, whatever their diet (14)	Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test) Behavioural evidence that cows are drinking Water intake	Inspection of water points Analysis of water source
Provision of water points (troughs or drinkers) should ensure that cows do not need to wait too long, nor compete for water, and allow them to put their mouths into the water (12, 13)	Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test) Waiting and agonistic behaviours at water points Observation that cows do put their mouths into the water	Inspection of water points Location of water points

Table 1 addresses the quality and provision of feed and water. The measures used to monitor compliance with recommendations involve animal-based measures (e.g. measure of nutritional status,

behaviour at water points), inspection of records (e.g. fertility records), veterinary procedures, such as blood samples for "metabolic profiles", indicators of metabolic disorders (e.g. βOH butyrate as an indicator of ketosis) and non-animal-based measures, such as inspection of facilities (e.g. feeders, water points). Some of the listed measures are not direct measures of welfare but diagnostic tools used to identify that a welfare problem is likely to be present or to develop. For example, a reduction in milk protein concentration is not a welfare problem *per se*, but it is a good early indicator of excessive loss of body condition in early lactation, most probably due to inadequate feeding.

Table 2: Abbreviated list of recommendations related to HOUSING AND EQUIPMENT, as presented in the EFSA Scientific Opinion on the welfare of dairy cows (EFSA, 2009b), together with a list of potential animal- and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The measures identified in this table are sometimes described in broad terms to cover several more specific measures. The complete text of the recommendation(s) is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See the Glossary for definitions of the terms animal-based and non-animal-based.

Recommendations (EFSA, 2009b)	Animal-based measures	Non-animal-based measures
In cubicle houses there should be at least as many cubicles as there are cows in the house (24)	Lying in passage Agonistic behaviours (e.g. chasing-up from cubicles) Time spent lying down Time spent standing Hock, knee and skin lesions and swellings	Number of cubicles per animal
Where cubicles are used, they should be wide enough, in relation to the size of the cows (at least 1.8 times width at hips), to minimise any movement difficulties or teat trampling. Injuries to the cows should be monitored and cubicles modified or replaced if repeated injuries occur because of poor design (21, 23, 25)	Difficulties in changing positions (standing up and lying down behaviour) Time spent standing Time spent lying down Shifting weight from one foot to another Posture of cow in cubicle (cows lying with legs extended to another cubicle) Teat injuries Lying in passage Hock, knee and skin lesions and swellings Colliding with equipment when standing or lying down	Cubicle dimensions and design
Cubicles and tie-stalls should be designed so that the forward movement of the cow is not thwarted when changing position from lying to standing (20)	Getting up with front legs first Dog sitting Colliding with equipment when standing or lying down Time spent standing Time spent lying down Cows lying in passage Skin lesions Hock, knee and skin lesions, and swellings	Cubicle dimensions and design Arrangement of neck rail or brisket board
Cows or heifers kept in buildings should be provided with an area bedded with sufficient dry, compressible, non-slippery material that does not lead to skin lesions (43)	Hock, knee and skin lesions and swellings Time spent lying down Cleanliness of animals high up on legs and on back	Number of cubicles
Housing and ventilation should be able to provide sufficient air movement to prevent heat stress in summer conditions (33)	Sweating, increased body temperature Water intake Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test) Feed intake	Temperature/humidity index Measures of ventilation inlet and outlet
Gas concentrations in dairy cow houses should not exceed 10 ppm ammonia, 0.5 ppm H_2S (37)	Animals coughing Watery eyes Respiratory distress and collapse	Gas (ammonia, H_2S, carbon dioxide) concentration

The floor surface and housing system should be such that cows can walk normally without slipping or injury. Cows should not be caused to stand or walk for prolonged periods on concrete floors or floors that are wet or covered with slurry (45, 51)	Abnormal walking movement Slipping and falling Agonistic behaviours Foot lesions (claw and skin) Leg injuries and disorders associated with slipping Measures of lameness Animals standing in water/slurry	Floor surface, dimensions of walking area, depth of slurry Time in collecting yard
When possible, dairy cows and heifers should be given access to well managed pasture or other suitable outdoor conditions, at least during summer time or dry weather (50)	Measures of lameness	Absence of tethers; and evidence that housing is designed for free movement (e.g. free stalls of straw yards) Records being kept for the number of days cows and heifers are let out to pasture. Access to pasture or other outdoor area
Electric cow trainers should not be used (52)	Skin lesions	Presence of electric cow trainers
Minority Opinion: There is sufficient evidence for poor welfare in dairy cattle held in tie-stalls. It is recommended that dairy cattle should not be routinely kept in tie-stalls as a housing system (49)	Difficulties in changing position (standing up and lying down behaviour) Grooming behaviour in different parts of the body Abnormal social interaction and exercise Absence of normal range of resting postures	Absence of tethers; and evidence that housing is designed for free movement (e.g. free stalls of straw yards) Access to pasture or other outdoor area

Table 2 addresses the systems used to house dairy cows and the equipment used in them. Animal-based measures include observations (e.g. abnormal walking movements, lesions of skin, knees, hocks and feet) and inspection of records (e.g. lameness). Non-animal-based measures include inspection of facilities (e.g. measurements of cubicle dimensions). Appropriate selection of a sufficiently diverse range of measures can determine the impact of housing and equipment factors on specific welfare outcomes (e.g. mastitis, lameness, injury, thermal discomfort).

Table 3: Abbreviated list of recommendations related to MANAGEMENT, INCLUDING MANAGEMENT AT CALVING, as presented in the Scientific Opinion on the welfare of dairy cows (EFSA, 2009b), together with a list of potential animal- and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The measures identified in this table are sometimes described in broad terms to cover several more specific measures. The complete text of the recommendation(s) is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See the Glossary for definitions of the terms animal-based and non-animal-based.

Recommendations (EFSA, 2009b)	Animal-based measures	Non-animal-based measures
Dairy housing and management should ensure that there are sufficient calving pens (70) Dairy cows housed in buildings should be moved to individual calving pens with some contact with other cows in order to minimise welfare problems (69)	Cows interfering with other cows during calving Calves not accepted by cows Calves body conditions, calf mortality and neonatal disease	Number of calving pens available according to seasonality of calving Location of calving pens in close proximity to other cows/allowing contact with other cows
To reduce risk of dystocia, particularly at first calving, heifers should be inseminated after they reach the mature weight for the breed and only sires known to have low incidence of dystocia should be used to breed heifers (85)	Dystocia	Age at insemination or calving Records of sire selection Breeding value of sire calving ease
Downer cows should have food and water within easy reach, care should be taken to prevent spilling of water that would contact the cow, and manual assistance should be offered at regular intervals to aid recumbent animals in their attempts to stand. If the prognosis is hopeless or very poor, then euthanasia on welfare grounds should be advised (111)	Downer cows Evidence of wet coat in downer cows Evidence that cow can feed or drink water	Presence of sick-pens Procedure for handling of downer cows Presence of decision rules tree and for euthanasia of downer cows
On-farm killing of downer cows or other cattle should be carried out only by the use of a humane method (112)		Established procedure and equipment available for killing downer cows
Stockpersons should receive training in animal management methods and animal welfare (102)	Avoidance behaviour or aggression to humans, increased reactivity to humans	Evidence of training courses taken by stockpersons
Electric goads should not be used on cattle (103)	Avoidance behaviour to humans	Evidence of electric goads on farm
Cattle should be marked using micro-chips, freeze-branding or tags that involve small injuries. Hot-iron branding causes severe pain and should not be used (105)	Evidence of marking methods Infections from marking	Tags or marking equipment on farm. Record of marking methods
De-horning of heifers and cows should be avoided wherever possible and carried out only with the use of regional anaesthesia and analgesia. Disbudding when the animals are calves should be carried out, if horn removal is necessary, but anaesthesia and analgesia should be used (106)	Presence of horns in a group of calves at the age limit above which disbudding cannot be carried out	Record of procedures and equipment for local anaesthesia and analgesia usage Evidence of veterinarian's work during disbudding or dehorning procedure Record of breeding polled cattle

The tails of cattle, including dairy cows, should not be docked (107)	Docked tails observable

Table 3 addresses the recommendations regarding general stockmanship, management around calving, management of downer cows and mutilations due to routine procedures, such as marking of animals or dehorning. In most cases, animal-based measures are used to assess compliance with recommendations (e.g. docked tails observed, dystocia). However, fulfilment of some of the recommendations is more reliably checked using resource-based measures (e.g. evidence of electric goads on farm). Resource-based measures can even provide more specific information than animal-based measures alone (e.g. availability of calving pens).

Table 4: Abbreviated list of recommendations related to MILKING AND MASTITIS, as presented in the EFSA Scientific Opinion on the welfare of dairy cows (EFSA, 2009b), together with a list of potential animal- and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The measures identified in this table are sometimes described in broad terms to cover several more specific measures. The complete text of the recommendation(s) is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See the Glossary for definitions of the terms animal-based and non-animal-based.

Recommendations (EFSA, 2009b)	Animal-based measures	Non-animal-based measures
Milking equipment should be designed, constructed, maintained, managed, cleaned and disinfected so that to the risk of injury, pain and disease in dairy cows is minimised (55)	Time to enter milking area Stopping and turning behaviour, kicking off clusters Evidence of mastitis, teat injuries Avoidance of humans Residual milk	Records of milking machine maintenance
Cleaning of udders should take full account of the risk of transmission of pathogens (58)	Cleanliness of udder (especially teat end) Evidence of mastitis (e.g. clots and blood in milk, udder and teat inflammation and ulcers, somatic cell counts)	
When a milking robot is used, cows should be allowed to have access to food and water independently of visiting the robot, except for initial training purposes (61)	Non-milking visits to robot Duration of meals	Presence of free traffic situation (open gates to feeding area and water points that do not force animals to pass through the robot)
Robotic milking systems should be carefully adjusted and checked each day (63)	Reluctance to enter the robot unit Udder injuries, evidence of mastitis	Standard operation procedure for checking of robot
The prevalence of mastitis should be reduced by the treatment of clinical and subclinical disease, dry cow therapy, identification and elimination of carrier cows, prevention of transmission of infection from cow to cow or through the environment, and improvement of the immune system by minimising stress factors and by a controlled and nutritionally-balanced feed intake (84)	Clinical evidence of mastitis, including: fever and general malaise, teat and udder lesions and hypersensitivity, and clots and blood in milk, udder and teat inflammation and ulcers, somatic cell counts	Record of programme for prevention and control of mastitis, including surveillance using bacteriological examinations and somatic cell counts, therapeutic strategies, including the use of antimicrobials Records of programme for dry cow therapy, milking hygiene, culling policy
Pain management should be part of the treatment of clinical mastitis (82)	Behavioural evidence of pain (e.g. hypersensitivity to touch on teat or udder, reluctance to move)	Records of evidence of materials for pain relief and training

Table 4 addresses the recommendations necessary to ensure the correct operation of milking machines (including robot milkers), hygiene in the milking parlour, and the prevention and treatment of mastitis. The majority of measures used to assess compliance with recommendations are animal-based (e.g. evidence of teat lesions, reluctance of cows to enter the milking parlour). However, these need to be reinforced by recorded evidence that the farmer is implementing a satisfactory programme for milking machine maintenance and a proactive strategy for mastitis control.

Table 5: Abbreviated list of recommendations related to LOCOMOTOR DISORDERS, as presented in the EFSA Scientific Opinion on the welfare of dairy cows (EFSA, 2009a), together with a list of potential animal- and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The measures identified in th[is table] are sometimes described in broad terms to cover several more specific measures. The complete text of the recommendation(s) is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See the Glossary for definitions of the terms animal-based and non-animal-based.

Recommendations (EFSA, 2009b)	Animal-based measures	Non-animal-based measures
Because of the high risk of lameness in dairy cattle all dairy farmers should implement a lameness prevention programme (77)	Measures of lameness Measure of overgrown and misshapen hooves Clinical signs of infection in the hooves region	Records of foot inspection Facilities for foot bathing and foot inspection
Clinical cases of lameness should be given proper veterinary care. When systematic monitoring indicates an increasing prevalence, appropriate corrective measures should be taken at the herd level. On farms with a high prevalence of recognisable locomotor difficulties (e.g. approaching 10 %) there should be improvement of housing conditions, genetic strain and management practices (78)	Measures of lameness Evidence of discomfort when standing (e.g. paddling, resting a foot) Foot lesions, such as sole ulcer, sole haemorrhage, white line separation Infectious conditions of claw and skin (e.g. digital dermatitis)	Records of treatments administered
Pain relief should be provided during and after treatment for severe lameness (80)	Weight removed from the affected hoof, by corrective trim or application of a block	Facilities for hospitalisation of severely lame cows Evidence of knowledge of how to carry out pain management procedures Records of provision for pain relief (e.g. use of analgesic, provision of improved bedding)

Table 5 addresses the recommendations necessary to control locomotor disorders, including preventive measures, veterinary care and pain relief during and after treatment for severe lameness. Most of the measures used to assess compliance with recommendations are animal-based (e.g. lameness, foot lesions recordings), thus indicating the presence and severity of locomotor disorders on the farms. Non-animal-based measures are additionally used for evidence that the farmer is implementing an appropriate treatment with a pain relief programme and facilities for preventive treatments (e.g. hospital facilities, presence of foot bath).

Table 6: Table 1. Abbreviated list of recommendations related to DISEASE CONTROL, as presented in the EFSA Scientific Opinion on the welfare of dairy cows (EFSA, 2009b), together with a list of potential animal- and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The measures identified in this table are sometimes described in broad terms to cover several more specific measures. The complete text of the recommendation(s) is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See the Glossary for definitions of the terms animal-based and non-animal-based.

Recommendations (EFSA, 2009b)	Animal-based measures	Non-animal-based measures
Regardless of housing system, herd health and biosecurity programmes, continuously adapted to the unique situations of each individual enterprise, should be in place to prevent introduction of disease and pathogens to the dairy herds and to control spread within the herd (88)	Clinical signs of infectious diseases	Records of health and biosecurity programmes and of cattle movement adapted to unique farm situation
Biosecurity programmes should be supported by monitoring and documentation of diseases occurrence and variables like patterns of antibiotic resistance, and applied strategies for prevention and intervention should, when justified, be adapted along with new epidemiological information (89)	Evidence of infectious- and production-related diseases	Recording system for biosecurity programmes, including routines for staff and visitors, health control programmes and treatment, including laboratory examinations of diseased animals adapted to unique farm situation. Evidence of requirements for the introduction of new heifers and bulls (e.g. disease free status) Presence of quarantine facilities Evidence of disease free status of artificial insemination centres used by the farm
Efforts should be made to minimise the transport of animals, in particular, between herds, and when such transports are applied, special attention should be given to the reduction of associated risks of poor welfare and spread of infectious diseases (94)	Evidence of infectious diseases	Records of animal movements of quarantine and of management of newly introduced animals
Dairy farms should have facilities for severely ill or injured animals and such animals should be moved to these facilities as soon as possible Facilities for sick animals with infectious diseases should not be used for calving (96, 97)		Presence of sick-pens and (separate) calving pens Presence of facilities and records of their use

Table 6 addresses the recommendations necessary to reduce the incidence of disease. Thus, most of the measures are of a preventative nature, such as having a health plan and a biosecurity programme. Minimising the movement of animals between herds and moving diseased animals to a sick box are also important for reducing the spread of disease. These are mainly resource- and management-based measures. The animal-based measures are associated with evidence of infectious diseases, presumably to be followed by effective treatment to minimise spread. The numerous clinical signs associated with the disease are not listed in the table, since they can be obtained from standard veterinary text books.

Table 7: Table 2. Abbreviated list of recommendations related to GENETICS AND BREEDING, as presented in the EFSA Scientific Opinion on the welfare of dairy cows (EFSA, 2009b), together with a list of potential animal- and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The measures identified in this table are sometimes described in broad terms to cover several more specific measures. The complete text of the recommendation(s) is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See the Glossary for definitions of the terms animal-based and non-animal-based.

Recommendations (EFSA, 2009b)	Animal-based measures	Non-animal-based measures
The genetics of dairy cattle should be taken into account when designing housing and management methods for these animals (1)	See Table 2 for list of measures	See Table 2 for list of measures
There is an urgent need to improve dairy cow welfare through changes in the criteria used for genetic selection. These changes should result in animals in which there are fewer demands on their mechanisms of adaptability, less lameness, less mastitis, less reproductive and metabolic disorders, even when these may conflict with selection for milk yield (2, 3)	Measures of length of productive life (e.g. changes in mortality and culling rate, age distribution within herd) Outcome indicators for lameness, mastitis, reproductive and metabolic disorders (Tables 1, 4, 5) *NB: It is not possible to assess the overall impact of genetics at the farm or national level from measures made on single visits to individual farms*	Record of sire selection in relation to welfare indicators (lameness, mastitis, reproductive and metabolic disorders)
In order to avoid poor welfare, such as that associated with reproductive disorders and loss of robustness, the breeding procedures for dairy cattle should be designed to reduce inbreeding (6)		Records of sire and dam selection
Wherever transgenesis or cloning procedures are carried out on dairy cattle, any effects of the procedures and of any genetic change on the welfare of the animals should be evaluated using an appropriate range of animal welfare indicators. The results of such welfare evaluation studies should be taken into account when considering whether or not to produce or farm such animals (9)	Evidence of pain, distress and lasting harm associated with the processes themselves using an appropriate range of animal welfare indicators for the expected consequences of transgenesis (see Guidance on the risk assessment of food and feed from genetically modified animals including animal health and welfare aspects, (EFSA, 2012c)).	

Table 7 addresses the recommendations necessary to reduce the adverse effects (referred to as consequences or outcomes in Figure 1) of genetic selection and breeding procedures. This topic was highlighted in the EFSA Scientific Opinion (EFSA, 2009b) as a particularly important area for action. A high proportion of the animal-based measures listed elsewhere, including all of those relevant to lameness, mastitis, reproductive and metabolic disorders, are relevant here. In addition, records of selection and breeding procedures are needed.

Although many animal-based measures are simple and easy to use even under commercial conditions, in some cases, a measure may require further analysis in a laboratory (e.g. metabolic profiling), or may be time consuming to collect (e.g. changes in diurnal rhythm). However, with continued technical developments, especially those associated with automatic recording and precision livestock farming

techniques, it is likely that several currently impractical animal-based measures will become cheap and feasible on-farm in the future. For example, the time cows spend lying down is now one of the behaviour patterns that can be easily and relatively inexpensively recorded automatically (Ito et al., 2009).

Animal-based measures have usually been selected to identify animals that already have poor welfare or good welfare, hence the term welfare outcome indicator (Figure 1). However, it is also desirable to identify animals as early as possible whose welfare is decreasing or increasing, so that changes can be made before the individual is adversely affected, or in order to maximise benefits. Such measures could help to predict those animals at risk of poor welfare if no change or intervention is made and to promote good welfare where this can be achieved. For example, a high milk somatic cell count indicates an immune response to a bacterial infection of the udder. This may not be a substantial welfare problem for the animal at the time that it is detected, but if steps are not taken it may become a welfare problem if clinical mastitis develops. Similarly, changes in time spent feeding and resting may predict the later development of illness (Weary et al., 2009). Thus, some animal-based measures may be useful not only because they indicate a current welfare problem, but because they are an indicator of the start of a cascade of potential negative welfare outcomes that are to be avoided.

In this Opinion, the focus is on identification and quantification of indicators of dairy cow welfare on-farm, as in the EFSA Scientific Opinion (EFSA, 2009f). However, animals could be inspected either at the farm or during ante-mortem or post-mortem inspection in the slaughterhouse. Animal-based measures taken during ante-mortem inspection that provide information about welfare on-farm include identifying severe lameness, injuries, clinical disease, or starvation as indicated by body condition. There are also other ante-mortem and post-mortem slaughterhouse measures that provide information about welfare during transport, lairage and pre-slaughter handling (e.g. injuries, fear reactions).

Generally, such measures are better developed in meat animals and will therefore not be dealt with further in this Opinion (see, for example, the Scientific Opinion on the public health hazards to be covered by the inspection of meat (swine) (EFSA, 2011). However, they can be expected to be more important in subsequent Opinions on animal-based measures and welfare-outcome indicators.

2.1.2. Selection of measures

It was concluded that the measures necessary to investigate and check the fulfilment of the recommendations in the EFSA Scientific Opinion (EFSA, 2009b) should consider both input factors (resource- and management-based measures) and consequences (animal-based measures). These measures (see Appendix 1 for a full list) may be categorised as follows:

- Animal-based measures:
    - *Observations and measures* from the animals made during the welfare assessment on-farm, ante- or post-mortem. These are direct indicators (e.g. behaviour, clinical signs of injury or lameness). Some of these are veterinary procedures that can be obtained only by a veterinarian or other authorised individual (e.g. from a blood sample),
    - *Records* of animal breeding, milk yield and milk quality, fertility, health, etc. These are indirect indicators and may include records of animal-based measures obtained using automated methods (e.g. progesterone in milk samples, locomotion scoring from force-plate recordings).
- Non-animal-based measures (resource- and management-based):
    - *Observations and measures* of housing provided or of management used (e.g. cubicle dimensions, quality of bedding and floor surfaces),
    - Inspection of *documentation* (e.g. food provision strategies, foot care programme).

The selection of animal- and non-animal-based measures is governed by the areas of concern (nutrition and feeding, housing, genetics and management) as presented in the EFSA Scientific Opinions (EFSA, 2009c, d, e, f). The monitoring of problems relating to nutrition and feeding requires measures of nutritional status, milk yield and milk composition, biochemical tests on milk (and blood) and inspection of resources (e.g. feeders and feed quality). In the category of housing and environment, the majority of welfare indicators are animal-based measures (e.g. colliding with equipment when standing or lying down, skin injuries), backed up by measurements of resources (e.g. cubicle dimensions). In this case, the majority of the animal-based observations are consistent with those identified by Welfare Quality®. Inspection of the animals can give some indication of the impact of genetics and breeding on welfare but the largest amount of information can be gained from inspection of records of health, fertility and lifetime performance. Management issues relating to social behaviour, stockmanship and human-animal relationships can be obtained mostly from animal-based observations. These are well-described by Welfare Quality®. Assessment of issues relating to calving, milking, mastitis and lameness requires a combination of observations and records, backed up on occasion by veterinary procedures. The quality of biosecurity and health planning can only be assessed from inspection of records.

2.1.3. Use of measures

It would be quite unrealistic and also unnecessary to recruit all of the measures listed in Appendix 2 on every occasion that the welfare of dairy cows is to be assessed. They should be considered as a comprehensive toolbox, from which to select the range of measures necessary to address the specific objectives of a specific assessment. For example, extensive investigation of issues relating to the welfare of dairy cows (e.g. those that form part of an ongoing health plan) requires that observations of animals be supported by records of performance, fertility and health (e.g. diagnostic and medication records). These are necessary because it is not possible to obtain sufficient indication of welfare and the quality of husbandry on a dairy farm from observations made during a short visit, either for the creation of a farm-specific welfare plan to support farm management, or for purposes of legislation. On the other hand, an assessment of the impact of nutrition and feeding practices on productivity and welfare, including health, of dairy cows would select a very different set of indicators from the toolbox. Furthermore, an assessment made for legislative purposes, especially when intended for presentation as evidence in support of a ban on a particular management practice or the failure of a resource, would need to provide legally reliable evidence, including that from veterinary procedures, which may not normally be obtained from a routine welfare inspection. A portfolio of measures may also be incorporated into a HACCP principle-based programme or any other farm management strategy.

The animal-based measures highlighted in this Opinion, and summarised in Appendix 2, are deliberately general in their nature. In practice, they would be developed according to SOPs (standard operating procedures) leading to more detail about how to carry them out. This has already been undertaken for the measures in the Welfare Quality® dairy cattle protocol (Welfare Quality®, 2009).

Some of the changes in dairy cow management that would be needed in order to improve welfare can be achieved quite rapidly in a period of hours or days, but others may take weeks or months. However, changes in buildings and genetic selection may take many years (see Section 2.4.4). For example, a foot problem might be resolved by the removal of sharp stones from a pathway, or may require flooring modification so that cows do not slip or a change in cubicle length so that cows do not have to stand with their feet in a wet passageway. Other changes may only be achieved over a much longer period of time (e.g. by selecting cows for improved hoof-horn quality and resistance to lameness). A defined set of animal-based measures is needed to provide a baseline or benchmark for comparison over time. Such benchmarking of a harmonised set of standardised animal-based measures is especially useful to confirm improvements in dairy cow welfare following a change.

Within the EU there is increasing emphasis on changing the official control according to the estimated risk. This is specified within the 'hygiene package' of legislation (Regulation (EC) No 882/2004[6]) to verify compliance with animal disease control and welfare rules. It is stated that the frequency with which these official controls of animal welfare are carried out shall be proportional to the risk, which is called target inspection or risk-based inspection or surveillance.

Below is a list of some of the potential areas of implementation of protocols for assessment of dairy cow welfare:

- By a farmer to support his/her management decisions,
- By a farmer to track changes in welfare as a result of changes in management or environment,
- By a consultant or adviser to the farmer,
- By breeding companies as part of their selection procedures,
- By an auditing or accreditation organisation to check that a farm satisfies the necessary criteria to be part of a quality assurance or labelling scheme,
- By the competent/responsible authority to check that a farm satisfies animal welfare requirements according to legislation, and evaluate effects in practice of changes in animal welfare legislation,
- By the competent/responsible authority as part of pre-testing the welfare consequences of any future housing or technical development before it goes on the market,
- By scientists during an experiment, so that their results can be compared with the results collected by other scientists.

2.1.4. Summary of findings from a review of methodologies and from a pilot project to investigate the relationship between animal welfare hazards and animal-based measures

In order to explore further a possible route of how to proceed towards quantitative risk assessment of animal welfare, a report was commissioned from the Sanisys consulting company (Presi and Reist, 2011). The specific question was to describe methods and tools to ascertain and qualify correspondence between input factors (animal welfare hazards) and animal-based measures (adverse effects) (Figure 1) that could be applied to evaluate and validate the use of animal-based measures in monitoring animal welfare. Amongst other methods, this report suggested discriminant analysis and model-based classification trees with random forest, as two methodological approaches to explore the links between animal-based measures and hazards. Whilst common epidemiological analyses identify risk factors and quantify the strength of the factor for a given welfare problem, these proposed methods aim at identifying animal-based measures which allow discrimination between herds at risk of poor welfare. They may also be used to predict a certain outcome (i.e. animal-based measure above a predefined threshold) from the presence of a factor.

Given that there was access to a large dataset, a follow up study was commissioned (Brenninkmeyer et al., 2012) that applied these methods on the selected animal-based measures of integument alterations and locomotion disorders as output variables. The main goal was to classify farms at risk correctly (i.e. farms exceeding a cut-off prevalence), thus identifying and quantifying associations between factors (hazards), as identified by the EFSA Scientific Opinion on the welfare of dairy cows (EFSA, 2009d, e) and animal-based measures (of adverse effects). Data were obtained from 96 cubicle-housed dairy herds in Austria and Germany collected by trained observers with inter-observer reliability testing

[6] Regulation (EC) No 882/2004 of the European Parliament and of the Council of 29 April 2004 on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules. OJ L 191, 28.5.2004, p. 1-59.

before and after data collection. In addition to the output variables, a set of variables from housing and management were included as hazards (EFSA, 2009d, e). In total, 11 different scenarios evaluating the associations between different subsets of animal-based measures and adverse effects (output variables) on the one hand and hazards and adverse effects on the other hand were calculated.

All classification tree models using random forest analysis and most models using discriminant analysis identified risk farms with misclassification rates below chance level, with classification trees performing consistently better than discriminant analysis. This can be explained by the fact that, in contrast to discriminant analysis, classification tree models account for interactions between independent variables. A better performance of classification tree models makes sense though, both from a biological and a mathematical point of view. Furthermore, the results obtained with the current dataset indicated that animal-based measures taken from a farm visit classified farms at risk slightly better than resource-based measures or measures from milk recording systems.

In conclusion, this follow-up study supported that the methodologies suggested in the first procurement (Presi and Reist, 2011) were suited to analyse effectively the complex relationships between animal-based measures and hazards when it comes to the identification of farms at risk from poor welfare. It further suggests focusing on classification tree models for additional analyses. For further exploration, user friendly database management systems to store data in a standardised way are required, as well as larger and comprehensive data sets comprising specific factors, which allow models to be built based on state-of-the-art scientific evidence, as suggested in the first procurement (Presi and Reist, 2011).

2.2. How the assessment protocols suggested by the Welfare Quality® project cover the main hazards identified in EFSA Scientific Opinions and vice versa for an overall classification of the welfare situation (ToR 2)

2.2.1. Procedures to address this question

This term of reference deals with how the dairy cattle assessment protocol suggested by the Welfare Quality® project covers the main hazards (referred to as input factors in Figure 1) identified in the EFSA Scientific Opinions (EFSA 2009c, d, e, f) on the welfare of dairy cows. In the original EFSA Opinions, 80 unique hazards were identified, but since a particular hazard may be a main hazard in one housing system or situation but less important in another, the four different risk analyses were based on a total of 555 hazard characterisations. The first step to answer the ToR for this current mandate was therefore to reduce this long list to a short list of the main hazards. To do this, the top two hazard characterisations were identified for each of the four EFSA Scientific Opinions risk assessment (EFSA, 2009c, d, e, f) (metabolic and reproductive disorders, udder disorders, leg and locomotion problems, behavioural disorders, fear and pain) for each housing system (cubicle housing, tie-stall, straw yards and pasture) and for each hazard category (housing, management, genetics, nutrition and feeding). In addition, any hazard with a risk estimate score of greater than 10 was also selected.

This process reduced the original list of 555 hazards named in the EFSA Opinions, to a short list of 136 main hazards, and when duplicate hazards that occurred in more than one housing system or assessment report were removed, this resulted in 55 unique hazards. For transparency, Table 8 highlights how many main hazards were selected from the total number identified in the EFSA Scientific Opinion (EFSA, 2009c, d, e, f).

Table 8: Table 3. Number of hazards selected (for detailed consideration) and all hazards (in parentheses) by the respective category combinations, as originally proposed in the EFSA Scientific Opinions (EFSA, 2009c, d, e, f). The hazards are grouped horizontally according to which Scientific Opinion and to which housing system they refer, and vertically according to the four hazard categories used in the Scientific Opinion. For each combination of housing system and hazard category, the top-ranking hazards (based on the risk estimate value), as well as all hazards with a risk estimate >10, were selected in order to reduce the number of hazards and to focus on the main hazards by category.

		Hazard category				
Report	Housing system	Genetics	Housing	Management	Nutrition and feeding	Total
Behaviour	Cubicle houses	2 (3)	5 (24)	2 (16)	2 (6)	11 (49)
	Pasture	2 (3)	2 (11)	2 (15)	2 (3)	8 (32)
	Straw yards	2 (3)	3 (20)	2 (15)	2 (6)	9 (44)
	Tie-stalls	2 (3)	8 (22)	2 (12)	2 (6)	14 (43)
Leg problems &locomotion	Cubicle houses	2 (2)	4 (14)	3 (9)	2 (4)	11 (29)
	Pasture	2 (2)	2 (6)	2 (9)	0 (0)	6 (17)
	Straw yards	2 (2)	2 (9)	2 (9)	2 (4)	8 (24)
	Tie-stalls	2 (2)	2 (8)	2 (8)	2 (4)	8 (22)
Metabolic and reproduction	Cubicle houses	2 (4)	2 (22)	2 (17)	0 (11)	6 (54)
	Pasture	2 (4)	2 (7)	2 (16)	2 (6)	8 (33)
	Straw yards	2 (4)	2 (19)	2 (17)	3 (11)	9 (51)
	Tie-stalls	2 (4)	2 (18)	2 (15)	2 (11)	8 (48)
Udder problems	Cubicle houses	2 (2)	2 (14)	2 (12)	0 (2)	6 (30)
	Pasture	2 (2)	2 (7)	2 (12)	2 (2)	8 (23)
	Straw yards	2 (2)	2 (12)	2 (12)	2 (2)	8 (28)
	Tie-stalls	2 (2)	2 (13)	2 (11)	2 (2)	8 (28)
Total	Selected (all)	32 (44)	44 (226)	33 (205)	27 (80)	136 (555)

The 31 measures used in the Welfare Quality® dairy protocol (Welfare Quality®, 2009) and the 55 unique main hazards from the EFSA Scientific Opinions (EFSA, 2009c, d, e, f) were then placed in a table with rows showing the different main hazards characterised in the EFSA Scientific Opinion and columns showing the Welfare Quality® dairy protocol measures. This table is presented in Appendix 3 and illustrates how the dairy cattle assessment protocol suggested by the Welfare Quality® project covers the main hazards identified in the EFSA Scientific Opinions and vice versa. The decisions, about when a Welfare Quality® measure addressed a specific hazard characterised in the EFSA Scientific Opinions and vice versa, were taken by members of the Working Group and experts with experience in animal welfare and husbandry, some of whom were also involved in the development of the Welfare Quality® assessment protocols. The results of this exercise are also presented in Appendix 3 and are summarised in Tables 9 and 10.

2.2.2. Main findings and issues

There were three adverse effects (referred to as consequences or outcomes in Figure 1) of the hazards identified in the EFSA Opinions that were not covered by the Welfare Quality® protocol (Number of adverse effects of the hazards, identified in the EFSA Opinions, that were assessed by measures in the Welfare Quality® dairy cattle protocol). These were 'increased constraint on the time available for activities' as a consequence of high genetic potential for production due to selection ignoring other traits; 'thermal discomfort' as a consequence of inappropriate temperature and humidity; and 'behaviour disruption' as a consequence of inadequate biosecurity (Appendix 3). Assessing constraints and disruption of behaviour would require extensive and time consuming behavioural observations to detect them. This may be one of the reasons why they were not covered by any of the measures within the Welfare Quality® protocol, which was designed to be carried out during a visit of less than one day duration. However, it highlights the problem that limitations imposed on a protocol will ultimately limit which hazards can be detected.

Table 9: Number of adverse effects of the hazards, identified in the EFSA Opinions, that were assessed by measures in the Welfare Quality® dairy cattle protocol.

	Number of Welfare Quality® measures										
	0	1	2	3	4	5	6	7	8	9	10
Number of adverse effects	3	6	9	2	14	12	2	0	2	0	2

In some cases, adverse effects of the hazards were covered by more than one Welfare Quality® measure (Table 9). The two adverse effects for which there were ten potential Welfare Quality® measures were related to the hazards 'inadequate transition feeding' and 'underfeeding', and more specifically to the adverse effects of 'ketosis, decreased fertility, immunosuppression'. These are rather general adverse effects and could be detected by several of the measures within the criteria 'absence of disease', as well as by body condition scoring of the animal.

There were nine measures in the Welfare Quality® protocol that were not linked to a main hazard identified in the EFSA Opinions (Table 10). These were those related to adequacy of water supply, cleanliness of the resting area and whether the animal was tethered or had access to an outdoor area (Appendix 3). However, these hazards were considered in the EFSA Opinions (referred to as inputs or factors in Figure 1) but did not rank as a main hazard, according to the way that these were defined here. Thus, it was concluded that the EFSA Opinions did not overlook any main hazards that were identified during the development of the Welfare Quality® protocol. However, this did not consider the positive emotional state, which is an outcome (referred to as a consequence in **Error! Reference source not found.**).

On the other hand, there were several Welfare Quality® measures that were related to the adverse effects of several hazards (Table 10). This may suggest that only these Welfare Quality® measures are not specific to a particular hazard. This is an advantage if the intention is to scan for the likely presence of hazards and their corresponding adverse effects (consequences or outcomes) but not necessarily identify them. It would be a disadvantage if it is important to be able to link a specific measure to a specific adverse effect. The clearest example of this is body condition score that covered 38 hazards. The next two Welfare Quality® measures that covered most hazards were the measures of lameness in loose housed and or tied cattle (Appendix 3).

Table 10: Number of Welfare Quality® measures defined by the number of times it is related to an adverse effect in the EFSA Scientific Opinions.

	Number of adverse effects covered by a given Welfare Quality® measure													
	0	1	2	3	4	6	9	11	12	13	15	16	17	38
Number of Welfare Quality® measures	0	3	1	1	5	1	9	1	2	1	1	1	2	1

In summary, the degree of overlap between the main hazards identified in the EFSA Scientific Opinions and the Welfare Quality® dairy cattle protocol is large. There are nevertheless several issues that have arisen as a consequence of addressing this ToR that are worthy of discussion.

2.2.3. Interpretation and implementation

The Welfare Quality® project identifies, whenever possible, an animal-based measure in its protocol. This measure is very clearly linked to the 12 Welfare Quality® criteria (see Section 1.1), but it is not always as clearly linked to a specific adverse effect presented in the EFSA Scientific Opinions. On the other hand, the EFSA Opinions is very transparent in identifying hazards and their adverse effects, but does not give comprehensive information about which animal-based measures should be used to describe these adverse effects in practice. In other words, the links between input factors on the left-hand side of Figure 1 and the outcome consequences on the right-hand side are not clear (see Figure 1). This problem in linking Welfare Quality® protocols to EFSA hazards is made difficult by the fact that an EFSA identified hazard may lead to several consequences and a measure in the Welfare Quality® protocol could have several underlying causal factors.

In some cases, the Welfare Quality® measure can be considered a reliable proxy for the adverse effect noted in the EFSA Scientific Opinions, even if they are not identical. For example, in the EFSA Opinions a consequence of heat stress due to inadequate ventilation was said to be immunosuppression, with the implied increased risk that the animal becomes sick. Although there are animal-based measures of immunosuppression they involve blood sampling and analysis, and so cannot be considered practical as welfare-outcome indicators under field conditions. The Welfare Quality® protocol focuses only on whether or not the animal is actually sick, by having measures in its protocol related to nasal discharge, coughing, etc. Here, there is a link between the Welfare Quality® measures of disease and the EFSA consequence of immunosuppression, but it is not a simple one-to-one link between risk factor (heat stress) and welfare outcome (being sick). An animal can be immunosuppressed but not sick and it can be sick without necessarily being immunosuppressed beforehand.

Another unresolved issue is the following. Often, a particular hazard will lead to several adverse effects. For example, the EFSA Scientific Opinions identified the hazard 'absence of bedding material', which can lead to several different consequences, such as systematic mastitis, leg injuries, skin and claw lesions, etc. The Welfare Quality® project only used the animal-based measure 'damage to the integument, including bare patches and injuries'. However, it is not fully known if the presence of direct damage to the integument due to lack of bedding, as identified in the Welfare Quality® protocol, would also indicate that there were indirect effects (e.g. higher occurrence of mastitis, gastro-intestinal or other infections).

The discrepancies between the EFSA Scientific Opinions and the Welfare Quality® protocols occurred because these two reports had different starting points. It was a stated requirement when developing the Welfare Quality® protocol that the measures should be of a type that did not require a trained veterinarian or ethologist to be able to record them. The aim was that any person with good animal knowledge could perform them reliably after training. The adverse effects in the EFSA Scientific Opinions are often expressed in terms of a veterinary diagnosis or experimental studies. On

the other hand, if the cow is sick with the disorders specified in the EFSA Scientific Opinions, then the Welfare Quality® protocol will, with all probability, detect it under the criteria 'absence of disease' or through a reduced body condition score, but it will not be associated with a specific diagnosis.

Furthermore, the Welfare Quality® protocol was designed to be carried out on-farm within one day, which means that, when appropriate, a resource-based measure is used instead of an animal-based measure. An example of this is the link between a 'lack of ease of movement' and 'being tethered'. There are animal-based measures to monitor ease of movement (e.g. colliding with equipment when getting up and lying down), but it was considered as reliable for the purposes of the Welfare Quality® protocol and considerably quicker to record whether or not the animal is tethered. The EFSA Scientific Opinions considered tied stalls as one of the systems to be evaluated and considered several different hazards associated with being tethered. It was therefore possible to identify many different adverse effects on dairy cow welfare in tie-stalls. For example, cow trainers are considered to lead to stress, fear and disturbed behaviour, according to the EFSA Scientific Opinions, but it is not specified how these states could be assessed. These terms are grouped in the Welfare Quality® project as indicators of the emotional state of the animal and are assessed using a qualitative behavioural assessment. Thus, again, there are links between the Welfare Quality® protocols and the EFSA Opinions, in that both focus on the key welfare issues, but they are not directly linked.

The measures of welfare outcomes presented in this report are those that can be made in practice by a competent farmer, veterinarian or other trained person, and can be justified by the closeness of their association to measures reported in published scientific experiments. Nevertheless they have certain limitations particular in regard to quantification of the intensity of poor welfare, (e.g. pain associated with injury, exhaustion associated with prolonged high metabolic demand). Other welfare outcomes (e.g. lameness, longevity) are more amenable to quantification (e.g. locomotion score, productive life index). However there is considerable variation in the scientific literature as to how these welfare outcomes should be defined and scored. The assessment of risks and benefits in relation to dairy cow welfare requires, wherever possible, quantitative or semi-quantitative measures of welfare outcomes (EFSA, 2012a). There is a need to develop improved methods for quantitative or semi-quantitative measurement of some welfare outcomes (e.g. pain associated with injury, exhaustion associated with prolonged high metabolic demand). There is also a need to develop more consistent methods for quantifying welfare outcomes such as lameness and longevity.

2.3. Identify which relevant animal welfare issues cannot be assessed using animal-based measures for dairy cows and what kind of alternative solutions are available to improve the situation (ToR 3)

2.3.1. Procedure to address this question

To address ToR 3, the tables developed for ToR 1 (how animal-based measures can be used to fulfil recommendations) and ToR 2 (linking the Welfare Quality® assessment protocol and hazards) were studied. The focus was on identifying hazards for which there were no corresponding animal-based outcome measures or for which the available animal-based measures did not adequately link poor welfare to the causing hazard,

From the table of recommendations presented in Appendix 1, a number of 'gaps' were found. However, it became apparent that there were similarities between some of the 'gaps' (or some of the welfare issues to which they applied) as to why animal-based measures are not currently being used, or why they can only be used with difficulty to assess the particularly relevant animal welfare issue. For this reason, this section is grouped into four main areas:

- welfare issues where alternative and more feasible measures are already available,
- genetics and breeding strategies,

- time constraints and possible automation of animal-based measures,
- animal-based measures that require specialist knowledge or skills.

Within each of these sections, the reasons why animal-based measures are not available or not used on a regular basis, as well as solutions that are available to improve the situation, are discussed.

2.3.2. Welfare issues for which alternative and more feasible non-animal-based measures are already available

Most of the welfare issues under this category were related to features of the environment that were either inappropriate in their original design or in the way they were used or provided to the animals. Although animal-based measures are available to address them, in almost all cases, it is more efficient to use a resource- or management-based measure to address the issue.

In theory, there are no hazards for animal welfare and no animal welfare issues that cannot be addressed using animal-based measures. However, there are practical constraints that may make it difficult to use some animal-based measures, or which make the use of resource- or management-based measures preferable in some situations.

A common reason is that the animal-based measure may not detect the hazard early enough to allow action to be taken to prevent animal welfare from being reduced. For example, recommendations 16 to 19 in Appendix 1 deal with quality of feed. These hazards can be detected through measures of nutritional status (e.g. poor body condition), but by that time the animal may have already suffered, possibly for a considerable period of time. Thus, a quicker and more practical solution is to monitor the diet quality carefully. Similarly, recommendations 69 to 72, and 86 relate to welfare issues associated with lack of proper facilities or management procedures for calving cows. Although animals will respond negatively to these hazards (inadequate maternal behaviour, thin calves, increased calf mortality, increased incidence of peri-parturient health problems, etc.), a more efficient solution would be to identify and correct these hazards directly.

Another common reason for delayed hazard detection is that the same poor outcome may be the result of many different hazards, and so the precise reason for the poor outcome cannot be determined. For example, recommendations 20 to 32, and 40 to 45 refer to problems related to housing design, mostly inadequate cubicle or tie-stall design, and lack of sufficient space. Animal-based measures are available to detect the result of these hazards, such as the ability to move freely, abnormal posture, injuries or skin lesions on knees or hocks, and lying in the passageway. However, these outcomes can also result from other hazards and so it would be very difficult to connect these measures directly to a specific hazard. Again, the solution would be simply to examine the adequacy of the cubicle design, as well as the number of cubicles, or the presence of narrow passageways. Such measures of 'engineering standards' are important when designing facilities. Getting it right at this stage can prevent later welfare problems. The situation is similar for the recommendations concerning number and inspection of water points (11-15), measurement of noxious gases, such as ammonia, CO_2 and H_2S (37, 38), light levels (39), temperature measurements (33 - 35), and ventilation rates (33), as well as recommendations 52, 53and 103, which deal with welfare issues associated with the use of cow trainers, electric goads and stray voltage, and recommendations 54 to 64, and 83 which address welfare issues related to milking equipment.

Recommendations 80, 82, 92-93, 96-100 and 104-113 relate to welfare issues associated with handling of sick cows (lack of appropriate facilities, inadequate management procedures, and misuse of therapeutic or analgesic drugs). Animal-based measures are not available or are limited, although it is clear that the animal will experience pain if treatments or minor surgical interventions are performed without proper anaesthesia and analgesia.

There is as yet no measure for thermal comfort in the Welfare Quality® protocol. This was highlighted in Appendix 3 as a main hazard for which there was no corresponding animal-based measure, although there are several animal-based measures that could potentially be used. These were listed in Appendix 1, next to recommendations related to temperature regulation. They include panting and sweating at high temperatures, and decreased respiration rate or signs of frost bite for low temperatures. Since heat and cold stress are not determined simply by air temperature, it is also necessary to assess other non-animal-based measures of thermal load, including air movement, humidity and thermal properties of lying surfaces.

2.3.3. Welfare issues related to genetics and breeding strategies

Recommendations 1-9 in Appendix 1 refer to hazards for the welfare of dairy cows attributable to genetics and breeding strategies. The genetic selection of dairy cattle is dominated by the major breeding companies. The individual farmer can contribute to the overall breeding strategy through selection of semen from bulls (and embryos from cows) with proven genetic merit for a range of traits relating to production, conformation and robustness. Most of the traits used by the breeding companies for the purposes of selection are animal-based (e.g. yield of milk and milk solids, body weight and conformation, somatic cell counts, fertility and ease of calving). Non-animal-based measures include records of preventive medicine (e.g. dry cow therapy to control mastitis) and routine foot care. However, it is difficult to separate out the genetic contributions to these illnesses from the environmental contributions and it is not possible to assess the overall impact of genetics on dairy cow welfare, at farm or national level, from measures of animal-based outcomes obtained on a single visit to an individual farm. When evaluating this hazard, the phenotypic expression of the genotypes of the current cows in the population have to be considered, as well as how the selection programmes implemented today may affect the welfare of future generations of dairy cows. There is, for example, convincing evidence that past selection programmes that gave major emphasis to increased milk yield have increased the incidence of clinical mastitis by about 0.5 % per year (Rupp and Boichard, 2003; Veerkamp et al., 2008). This response is cumulative, so one consequence of selection for increased yield from 1980 to the late 1990s has been an increase of 8-10 % in relative risk due to genetics. In the late 1990s, selection against mastitis was incorporated into the breeding programmes of many countries, but the emphasis placed on this trait has not yet been shown to bring about a decrease in the incidence of mastitis.

In the long term, breeding organisations should increase the emphasis on traits associated with good health, longevity and welfare, principally, fertility, mastitis and lameness. That this is possible has been demonstrated by data from Nordic countries (Norway, Sweden) where the genetic trend for mastitis in the Nordic Red cows shows a decreasing slope starting in about 2005 (Philipsson and Lindhe, 2003; Osteras et al., 2007). The success of these programmes depends on accurate and comprehensive records from individual farms of relevant data relating to sustained health and welfare. These include measures of fertility, ease of calving, conformation, somatic cell counts, incidence of mastitis and lameness, as well as longevity, and may include traits relating to behaviour and temperament.

2.3.4. Time constraints and automation of animal-based measures

Some of the animal-based measures can be obtained in a relatively short period, for example, an observation of advanced clinical mastitis or severe difficulty in walking, but other measures may require much longer. This is particularly true for outcome measures based on an animal's behaviour. Behavioural observations are in general very time consuming and some behaviours are difficult to detect, particularly those that do not occur frequently. For example, recommendation 11 refers to the fact that 'feeding systems should allow every individual cow to meet her needs for quantity and quality of feed'. Therefore, it is proposed that observations of behaviour at feeding time as a measure and agonistic interactions in the Welfare Quality® dairy cattle protocol (Welfare Quality®, 2009) are recorded. However, the observations would need to be carried out at times when cows are feeding. Similarly, failure to meet several of the recommendations would lead to cows spending less time than normal lying down. However, to obtain a reliable estimate of daily lying time, the cows would need to

be observed continuously for several days. Time constraints were probably the reason why there were no animal-based measures in the Welfare Quality® protocol for the hazards characterised by 'increased constraint on time available for activities' and 'behavioural disruption'. Both would require behaviour observations over several days or weeks to be addressed.

Fortunately, technology is becoming available that allows automatic monitoring of some behaviours, and some methods are already available on commercial farms. For example, data on the number of visits cows make to automated milking systems can help identify lame cows (Bach et al., 2007; Borderas et al., 2008), and this can be improved by equipment that measures how cows distribute their weight between their legs when standing (Pastell and Kujala, 2007; Pastell et al., 2010). Automated measures of feeding behaviour can identify cows that develop post-partum diseases, such as metritis (Huzzey et al., 2007), and can monitor hunger in milk fed calves (de Passillé et al., 2011). Other technology can be used in assessments even if this is not standard equipment on farms. For example, cheap accelerometers can measure the daily time spent lying down on commercial farms (Ito et al., 2009), while pedometers can measure the amount that cows walk, which can identify inadequate flooring in barns (Ouweltjes et al., 2011). Automated recording and analysis systems for other animal-based measures are already available and, if implemented, can support a welfare assessment programme.

2.3.5. Specialised training is necessary when taking the animal-based measures

As was discussed in Section 2.1.2, veterinary procedures may be involved in taking animal-based measures. Some of the animal-based measures may require the services of a veterinarian (e.g. care that involves the use of prescription only medicines, such as analgesics, antibiotics, or taking a blood sample or other invasive procedures). It is important that someone is responsible and that all roles are clearly defined and agreed. Thus, whether or not this animal-based measure is taken will depend on the availability of that expertise and associated recorded data.

Whoever is involved in any animal-based assessment, it is important that they are appropriately educated so that they fully understand their responsibilities, their role, that they are trained in the required technical procedures, such as recognition of clinical signs, scoring methodology, etc., and that they are competent in doing so. Any recording of a welfare indicator can fail if all these are not in place. Thus, specialist training in how to take the animal-based measure is necessary even for the farmer or animal caretaker. The attitude of the person to taking the measure and to animal-based measures in general can also influence whether or not relevant animal welfare issues are addressed using animal-based measures. Training is necessary to reduce inter- and intra-observer variation. Training and attitudes also influence management decisions to reduce or prevent welfare problems in various husbandry systems (see Section 2.4.2).

2.4. List the main factors in the various husbandry systems which have been scientifically proven to have negative effects on the welfare of dairy cows and to what extent these negative effects can be or not prevented through management (ToR 4)

2.4.1. Approach to address the question

The information compiled in the previous EFSA Scientific Opinions on the welfare of dairy cows provided some indications as to which hazards can be controlled through management. However, this specific aspect was not considered further in those Opinions. In the context of this mandate, it was not considered feasible to assess the available literature critically for an extensive list of main hazards. A process was therefore devised whereby the complete list of hazards, identified in the EFSA dairy cow Scientific Opinions, was reduced to a short list of main hazards. Thus, the starting point was the scientific evidence reviewed in the EFSA Scientific Opinions (EFSA, 2009c, d, e, f) and the list of 555 hazards identified in the various housing systems. This list was then shortened using the procedure outlined in Section 2.2.1 of this Scientific Opinion to identify 136 main factors. A Delphi approach was then used to individually collect working group expert opinion on this list of main factors and subsequently to discuss and interpret the given scores. In addition to deriving the results of the

analysis and the conclusions and recommendations from it, some time was also spent in this section discussing the issues that arose during the process of carrying out the exercise, since these were seen as relevant to the discussion on cattle welfare and to similar work in the future.

The Delphi technique (Rowe and Wright, 1999; Yousuf, 2007) is a group process used to survey and collect the opinions of experts on a particular subject, and has been used in various contexts in which it was deemed necessary to combine expert opinion from different individuals in a formalised and transparent way.

The Delphi approach consists of three steps:

- The selection of relevant questions to be asked (step 1),
- Individual scoring of these questions by experts (step 2),
- Option for changing the initial scores after being provided with the scores of the other experts, and consensus discussion (step 3).

The initial complete list of 555 hazards extracted from four EFSA Opinions for ToR 2 was used as a starting point for step 1. This first step was actually carried out when answering ToR 2 and is also explained in Section 2.2.1. In summary, for every group (combination of report, system and hazard category) the respective hazards were ranked by risk estimate, and (a) the two hazards with the highest risk estimates, and (b) all hazards with a risk estimate > 10 were selected for the next step of the Delphi approach. For the purposes of this ToR, these selected hazards were considered to be the main factors in the various husbandry systems which have been scientifically proven to have negative effects on the welfare of dairy cows.

In the second step, this list of the 136 most important hazards with categorisation, respective risk estimates and magnitude of adverse effects was sent to all experts. The experts selected were members of the Working Group with experience in animal welfare and animal husbandry. They were requested to express, independently for each hazard, his/her opinion as to whether this hazard could be prevented by management. A scoring system between 1 (very poor/low potential to control/mitigate hazard through management) to 5 (very good/high potential to control/mitigate hazard through management) was provided. Responses were pooled and summarised by calculating the mean and median, as well as the minimum and maximum (range of) scores for each hazard. Since it was identified quickly that for some hazards the full range of options (1 to 5; range 4) was scored, some time was spent in the Working Group discussing issues of clarification.

2.4.2. Areas requiring clarification during the process

These are relevant to the findings of the Delphi exercise and so will be discussed before the results of the exercise itself are presented.

The first observation made after step 2 was that there seemed to be substantial differences between experts in how they interpreted the term ‘management’. For some experts, this was anything that the animal owner (farm manager) or employed stockperson made a decision upon, ranging from daily

routines in handling the animals all the way to construction of buildings and what breed of animal to stock. Other experts took a narrower view and excluded those issues that were resource- or construction-demanding. In addition, the time scale of management was viewed differently, since, for some experts, management could include a long-term strategy, extending over several years, to achieve a goal, whereas, for others, management was limited to actions that took minutes, hours, but certainly not more than a few days to implement. Whether the animal owner or an employed stockperson was seen as the individual implementing the changes (in the context of hazard management) was considered important because an owner may have many more possibilities to implement costly/demanding management changes than an employed stockperson. For the purposes of

this Delphi exercise it was therefore decided that: (a) management was anything that the responsible persons (be it animal owner or stockperson) could easily do themselves (e.g. moving barriers/gates) but should exclude major activities, such as new buildings or replacing structural features of existing stables, (b) changes could be made in the short term (to be implemented and consequences seen within one week but excluding long-term management plans), and (c) without consideration of potential financial constraints (i.e. assuming that the managers could always take the decision to change if they wanted). It was not the intention to imply that changes such as genetic improvement and constructing a new building were not manageable, so the implications of focusing on management changes that could be made in the short-term are discussed later.

A second issue that arose when completing step 2 of the Delphi exercise was related to the wording of hazard itself. Although some hazards were repeated, they related to different housing systems and so the risk estimates for these hazards, as well as the possibilities for mitigating the hazard, may be different. Likewise, the main hazard may be the same (e.g. 'high genetic potential for production due to selection ignoring other traits') but the hazard specification differs (e.g. 'with or without good housing, nutrition and management'). If there is already good housing, nutrition and management, then the potential to mitigate the hazard in the short term by management is obviously small, if possible at all. Finally, the exact wording of the hazard has implications. For example, if the hazard is 'use of cow trainer', then there is no management option not to use the cow trainer, since this would define a new scenario (as pointed out before), whereas if the hazard is 'inadequate bedding' there is an option through management for this to be more or less inadequate. Drawing attention to these details was important during the process, and discussion of the initial results helped clarify several apparent disagreements between experts.

For some experts, the probability or likelihood that a change in management would actually be implemented should also be taken into consideration, whereas for others the question was intended only to deal with whether the hazard could be managed and not the likelihood of whether it would be managed (i.e. whether animal owners or stockmen were interested in implementing such changes). This issue is related to training, management and attitudes, and is discussed elsewhere in this report (Section 2.3.5), but the attitude of people towards managing a hazard is an important factor to take into consideration when interpreting the results of this ToR.

In the third Delphi step, the same hazard list, now with summary scores of all experts involved and instructions following the first round of clarification, was sent back to all experts with the request to compare their score to the summary results, and the option to: (a) adjust his/her own score, if deemed necessary, and (b) provide a written justification of his/her score, especially if it still deviated substantially from those of the other experts. These responses were also summarised for each hazard.

Finally, the information collected for each hazard was presented to the group, further analysed and interpreted with regards to the short-term management potential.

2.4.3. Statistical analysis

Final scores (Delphi step 3) provided by all experts were first summarised by hazard and described in terms of mean (average), median and range (min – max value). In order to assess the Delphi procedure, correlation of individual expert scores to the overall mean score (by hazard), as well as the changes between step 2 and step 3 scores were explored using frequency tables and Spearman's rank correlation routines.

In a second analysis step, average scores and average score ranges were compared between the factors (a) Report, (b) System, and (c) Hazard Category using a generalised linear model (GLM) approach with the three main effects and all 2-way interactions.

2.4.4. Results of the Delphi exercise

After the clarifying discussions, mainly of the definition of management and of the time frame considered for implementation (as described above) and rescoring with knowledge of the previously assigned scores, the new individual scores consistently showed higher correlation to the overall average, and the average range (difference between minimum and maximum score given for each hazard) dropped from 2.38 to 1.70. The frequency of wide ranges was substantially reduced. Therefore, the objective of the Delphi approach to reach a (better) consensus was reached. A slight drop in average management score was attributed to the modification of the definition of what can be achieved through management in the short-term.

In the initial GLM models for the two outcomes "average score" and "score range", none of the 2-way interactions were statistically significant, and they were dropped from the model. Subsequently, independent models containing the two main factors (a) System and (b) Hazard Category were run for the two outcomes. The factor "System" was not statistically significant in either model; however, there were strong differences in average management scores, as well as in ranges (indicating variability in expert scores) between the different hazard categories.

There was strong correlation between risk estimates and magnitudes for the included hazards (rSp=0.814). However, there was no correlation between average management scores and both RE and magnitude (rSp<|0.15|), implying that both low and high risk/magnitude hazards were classified as either manageable or not.

2.4.5. Assessment of management scores by hazard category and hazard risk estimates/magnitude

Hazards were plotted by hazard category based on: (a) management score (y axis), and (b) either risk estimate (RE) or magnitude (Mag) on a log scaled x-axis. Horizontal lines were included at scores 2.25 and 3.75, and vertical lines at the 10th and 90th percentile values for RE and Mag in order to identify those hazards most relevant for further exploration and discussion (Figure 2).

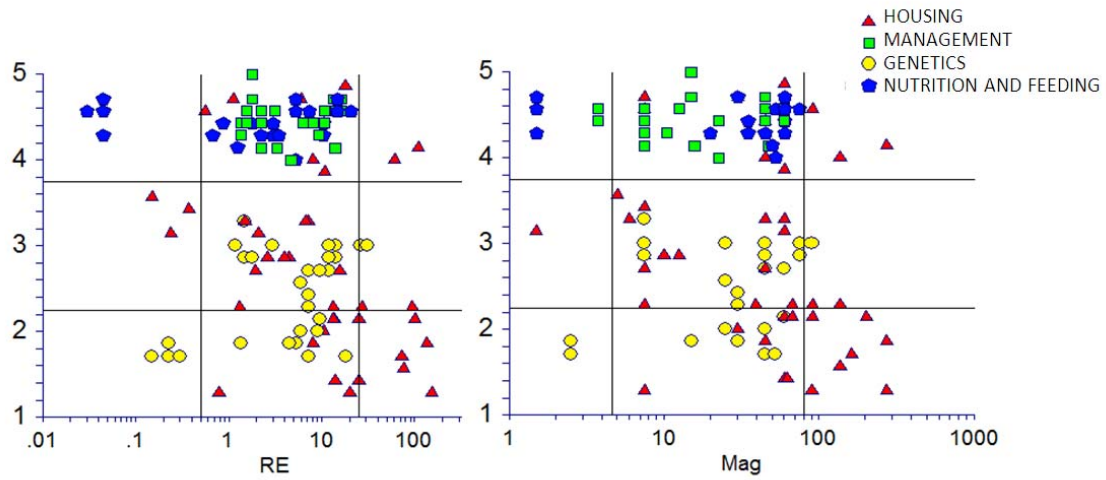

Figure 2: Average management scores (8 experts, y-axis) of all selected hazards by risk estimate (RE, left) and by magnitude of effect (Mag, right), coded by Hazard Category (Housing, Management, Genetics, Nutrition and Feeding). Horizontal lines indicate average management scores below 2.25 (poor) and above 3.75 (good), while vertical lines present the 10th and 90th percentile values of RE and Mag.

All management-, nutrition- and feeding-related hazards had high short term management scores (potential), and most were clustered in the intermediate risk estimate/magnitude category. There was a group of four nutrition hazards grouped in the top left quadrant (low risk – high management score). All of these were related to improper ration compositions, which were considered to be easily manageable.

Hazards related to the genetic composition of the stock had low to intermediate risk estimates/magnitude values, and were consistently scored to have only low to intermediate short-term management potential.

Housing-related hazards were present at all risk estimate/magnitude levels, and, depending on the respective hazard, were scored rather differently with respect to management potential. Those housing hazards that clustered in the lower right quadrant (high risk but low short term management option) were all either related to construction deficiencies in cubicle or tie-stall systems, or insufficient opportunity for exercise and social interaction (tie-stalls). Housing hazards with high risk or high magnitude values and high management potential (upper right corner) were related to easier to change issues, such as poor bedding. Some systems of husbandry (e.g. tie-stalls), by definition, do not permit freedom of movement and some other behaviour patterns relevant to welfare outcome indicators, and so their welfare assessment, can be partly based on the system itself. Although even within such inherently poor systems, there may be some leeway for improvement of some hazards.

From this exercise, estimated high risk hazards that were most easy to manage in the short-term were inadequate bedding in tie-stalls and cubical houses. The estimated high risk hazards that were most difficult to manage in the short-term were poor stall and cubicle design, being tied without exercise (zero grazing), being tied without exercise on average for 9 months(3 months grazing), lack of space for exercising, and inadequate floor in the space where cows walk.

2.4.6. Discussion

It was obvious that routine management-, nutrition- and feeding-related hazards had higher management potential, whereas the genetic composition of the herd and structural aspects of the building design had lower management potential. The most useful conclusion from the analysis in this respect is to say that the former hazards are those for which corrective action can usually be taken more quickly and easily, assuming the stockperson is willing and able to make the change, than for the latter set of hazards, which usually require a long-term commitment and may even require cooperation between various stakeholders in order for them to be managed.

This general conclusion can be clarified by some examples, which also highlight some reasons for the initial variation between experts in their scores. It may be theoretically easy to remove the management hazard ‘inadequate bedding’ by adding more bedding material, but the stockperson still needs the skills to manage it, so the quality of the bedding is also appropriate. Thus, even with high management potential, the attitude and skills of the farmer are likely to be very important. In a similar manner, ‘inappropriate ration composition’ can be corrected rather quickly. However, giving an appropriate diet requires that the stockperson continually adapts the diet to the needs of the individual animal for it to remain appropriate. In summary, this study has identified some hazards that usually have a high potential to be managed but there would probably need to be some form of advice and enforcement if the risk of these hazards occurring on a farm is to be reduced in practice,

Another type of example is provided within the area of genetics. If there is a hazard related to ‘high genetic potential for production due to selection ignoring other traits’, the results of the Delphi show that there is potential in the short-term to prevent some of the negative effects on the welfare of dairy cows only if there are management deficiencies on the farm. However, if this hazard occurs on a farm where there is already good management, then a further reduction of the negative effects can only be made in the long-term. In addition, these are probably managed best in collaboration with the breeding company. Breeding companies need feedback from farmers to evaluate genotype-environment

interactions and farmers should be encouraged to select animals on a wider range of traits than only those related to milk production. When selecting genotypes, farmers should consider the structure and characteristics of the farm, such as potential to grow or to buy feed appropriate with respect to the milk yield potential, the dimensions of cubicles and other housing installations. Similarly, it is too simplistic to group the category 'housing' because it is such a broad category of hazards covering all aspects, from a minor change in the position of a bar or detail in a stall, to a completely new floor in the whole building. In some countries (e.g. Sweden, Switzerland) there is a procedure for testing new housing systems in order to minimise the chances that a system is constructed that is inherently poor from an animal welfare point of view. This seems to be an important point, since the greater the effort and or time needed to implement the change the less likely it is to be perceived as manageable.

3. General discussion of issues related to the use of animal-based measures to assess dairy cows welfare on farm.

From the previous sections, it is clear that there are potentially many different animal-based measures that can be used to assess the welfare of dairy cows. Which measure is the most appropriate for a particular situation will depend on a number of different factors (e.g. the purpose of the assessment, the skills of the person collecting the measure, the conditions under which it is to be gathered and the time available to collect it, as well as financial constraints).

Several times in this report, the possibility of a 'toolbox' of validated, reliable animal-based measures to assess dairy cow welfare has been mentioned. It has been suggested that, depending on the reason for assessing the welfare, the most appropriate 'tools' can be selected from this box and used for that specific purpose. For example, a farmer wanting to improve one specific aspect of dairy cow welfare on his farm, a legislator wanting to evaluate whether changes in the legislation lead to improved dairy cow welfare in general, or a breeding company wanting to achieve a specific welfare related breeding goal, may all select different tools. There are, however, certain basic similarities in how this system would work, although all involve the process of monitoring, and these are highlighted below.

The first step is the identification of the goal. The second step is the identification of the population concerned and the definition and selection of the survey population. The third step is the selection of a combination of measures from the toolbox and the systematic collection of data. Following the analyses of the data, the results are interpreted. In some cases, a recommendation for action is developed and implemented. The goal and the survey population are reappraised and, when necessary, adapted, and then more data collected on the same measure(s) in order to verify whether the action has resulted in the intended effect. In many respects, this is similar to what is already being used with regard to animal health monitoring (Salman, 2003).

It became very clear from the work to answer ToRs 1 and 2, that there are interactions between indicators. For instance, a lame cow may be less competitive at the feed trough, so not having the most appropriate diet and therefore increasing its risk of metabolic disease, at the same time as it may lie for longer periods of time, so increasing its risk of mastitis if hygiene in the stall is not optimal on that particular farm. This example shows that links between hazards (e.g. flooring, hygiene in the stalls), consequences (e.g. pain leading to lameness, metabolic disorders), and animal-based measures (e.g. gait scoring and somatic cell count) are complex. Some of these complexities are listed below.

Hazards are not necessarily additive, nor of the same strength. In several cases, different hazards lead to the same welfare outcome (i.e. to the same consequence). In other cases, the same hazard may lead to several different welfare outcomes. Welfare outcomes can sometimes be assessed in a valid, accurate and robust way from one animal-based measure. Other welfare outcomes may require a combination of animal-based measures. A single animal-based measure may reflect several related welfare outcomes and so not be specific to any single consequence.

The work on ToR 1 and ToR 2 presented in Sections 2.1 and 2.2, the Welfare Quality® protocols and the EFSA Scientific Opinions on dairy cow welfare can all help when selecting appropriate welfare

outcome indicators to measure/detect the presence of welfare hazards and to monitor animal welfare. This is important for anybody wanting to assess or monitor animal welfare using animal-based measures, as it provides evidence of which combination(s) of measures might be chosen from the toolbox for a certain monitoring goal. However, as the work in this Scientific Opinion has shown, it is no easy task to combine information from different sources, originally collected with different aims. Furthermore, establishing only the links, but not their predictive capacities still does not allow us to select the most effective combination of indicators for a specific goal. For example, it would be very helpful to optimise the toolbox in a direction that would show which combination of indicators is best suited and most efficient in measuring the presence of the welfare outcomes and hazards of interest. To achieve this, one needs to identify and explore fully the presence and the predictive capacity of the correlations or associations within the hazard-outcome-indicator network. There are two main approaches to achieve this, expert elicitation or using databases. The expert elicitation approach is limited by the time and resources available to "score" the potentially large number of paired links. The database approach is limited by the lack of systematically collected field data, at the animal, herd and farm level, captured in a centralised database, from which to explore interactions between hazards, welfare outcomes and indicators using specific statistical tools (Presi and Reist, 2011). Issues related to the selection of experts and the lack of transparency in the final risk assessment are further disadvantages of the expert elicitation approach. On the other hand, the database approach carries the theoretical advantage of improved transparency and consistency of results based on "objective data" and the increasing possibility to move towards quantitative risk assessment for animal welfare.

Section 2.1.4 describes a possible approach to quantitative risk assessment of animal welfare prepared by the Sanisys consulting company (Presi and Reist, 2011). The document reports that in the field of social sciences and network analysis, statistical methods have been developed and applied to identify and describe complex associations between elements in populations or networks. Increasingly, such methods are also employed in animal science, for example, to describe animal movements in populations and thus identify direct contact structures relevant in the context of infectious disease outbreaks. The report describes how data collection can be from one or several sources (e.g. ongoing recordings, such as field records and monitoring, other databases, designated research projects, risk assessments and expert opinion). From these databases, automated data analysis routines can be used to facilitate communication between the different sources of information, to analyse the data and extract appropriate information in the form of a report. These reports can summarise the prevalence or incidence of factors and welfare outcome indicators, and benchmark results. However, the data analysis can also contribute towards identifying the links and the strengths of the links between input factors and welfare consequences that are currently lacking Brenninkmeyer et al., 2012 because the hazard-outcome-measures network is so complex. In this way, the database approach feeds back to help in selecting the most effective animal-based measures from the toolbox, and ultimately provides the type of information necessary for quantitative risk assessment of animal welfare. Some of these ideas were tested in a small 'proof of principle' follow-up study (Brenninkmeyer et al., 2012) using data from 96 dairy farms in two different countries (see Section 2.1.4).

Although these complex quantitative models have the potential to reveal the relative strength of links and interactions between factors, outcomes and measures, they are constrained both by the selection of factors and measures for inclusion in the model and by uncertainties attached to these factors and measures. Therefore, it is essential that application of these statistical models should always be preceded by expert elicitation of the specific objectives of the analysis and the hazards and measures necessary to address these specific objectives.

Within the dairy industry, there are many databases that could be used for detailed quantitative analysis of the links and interactions between hazards, animal- and non-animal-based measures and overall welfare outcomes. These include production records from individual farms, veterinary health schemes or dairy cooperatives that contain robust information on measures such as mortality, productivity, voluntary and involuntary culling, longevity (measured by number of completed lactations) and treatment records for diseases such as mastitis. Another example of a database derives from the fact that in response to the Bovine spongiform encephalopathy crisis, the Council of the

European Union implemented in 1997 a system of permanent identification of individual bovine animals enabling reliable traceability from birth to death. The system for the identification and registration of individual bovine animals includes maintaining a register on each holding (farm, market, etc.), cattle passports and national level computerised databases. Even if the information in such databases were limited in terms of its relevance to dairy cow welfare, it would still provide some animal-based measures at the national level (e.g. age at death and, possibly, also whether the animal was slaughtered on-farm or at a slaughterhouse).

One of the main advantages of this large-scale approach is the early detection of any potential problems leading to poor welfare as a result of trends in the dairy sector (e.g. changes in breeding goals, changes in raw ingredients in feed, etc.) Benchmarking of important animal-based measures on a large scale would give quicker feedback to policy makers on the effectiveness of legislation or other initiatives to improve dairy cow welfare. Surveillance of welfare outcome indicators is already established in other areas and there are similarities between what is discussed here and sign-based diagnosis in animal health and the EFSA Scientific Opinion on meat inspection (EFSA, 2011).

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. Animal-based measures can be effectively used in the evaluation of the welfare of dairy cows on farm in relation to laws, codes of practice, quality assurance schemes and management. Some of these measures are also appropriate for ante-mortem inspection and there are additional post-mortem animal-based measures which can be taken at the slaughterhouse.

2. For an overall assessment of welfare a wide range of measures is needed. However it is unnecessary to use all animal-based measures on every occasion. The choice of animal-based measures to use will depend upon the specific objectives of the assessment (e.g. legislation, quality assurance). The full list is comparable to a 'toolbox', from which the appropriate range of measures can be selected.

3. The list of animal-based measures shown in Appendix 2 is an attempt, based on currently available information, to develop this 'toolbox' from which to select animal-based measures that are most appropriate to specific objectives in the assessment of dairy cow welfare.

4. The animal-based measures considered to address the largest number of poor welfare outcomes, identified from the recommendations and hazards in the previous EFSA Scientific Opinions, were related to lameness, leg injuries, mastitis, colliding with equipment (structures) when getting up and lying down and poor body condition.

5. There is usually no simple one-to-one relationship between animal-based measures and input factors. Hence, to identify the cause of a specific welfare outcome several non-animal-based measures need to be used.

6. Some animal-based measures are early indicators (e.g. high somatic milk counts, time spent feeding and resting), and can be used to predict those animals at risk of poor welfare if no change or intervention is made.

7. Some animal-based measures can only be used for welfare outcome assessment if collected over a long period (e.g. length of productive life), in which case they are often best taken from historical records or recording systems.

8. Animal-based measures are taken directly from the animal or indirectly, for example using records Animal-based measures can be aggregated to give a herd or population level animal-based measure. Some animal-based measures are practicable for experimental use only, whilst others can be reliably used as welfare outcome indicators on farm or in the slaughterhouse.

9. Animal-based measures indicate the prevalence, incidence and intensity of welfare problems whereas non-animal-based measures indicate the potential for welfare problems. Some non-animal-based measures (e.g. access to water), are easy to measure and, when the association between them and animal-based measures is strong, may be used when it is more efficient to do so

10. Since most recommendations in the EFSA Scientific Opinion on the welfare of dairy cows concern resources and management, these non-animal-based measures are necessary to evaluate the extent to which recommendations have been fulfilled. However, in almost all cases, animal-based measures are necessary to determine whether or not the consequences for welfare intended by the recommendations have been achieved.

11. Some animal-based measures (e.g. measures of nutritional status, lameness) can be a consequence of the impact of a number of factors and can therefore contribute more to an overall welfare assessment than measures that are a consequence of a single factor. Others e.g.

involuntary culling rate, reflect a number of adverse outcomes such as mastitis, low fertility, and can therefore contribute more to an overall welfare assessment than reflect only a single adverse outcome.

12. The five animal-based measures that were most frequently named in Appendix 1 as being appropriate to address the recommendations, and hence major hazards in the EFSA Scientific Opinions were measures of 'lameness', 'hock, knee and skin lesions and swelling', 'colliding with equipment when standing or lying'. 'teat injuries' and 'evidence of mastitis'. The animal-based measure that was most frequently named in Appendix 3 as being appropriate to address the main hazards named in the Scientific Opinions was 'body condition score'

13. There are complex links and interactions between factors and their welfare outcomes. Statistical models are available to analyse these links but it is important to define at the outset the specific objectives of the statistical analysis. Systematic recording of non-animal-based measures (factors) and animal-based measures (welfare outcomes) is needed to generate the data base which should be used to help unravel and quantify the complex links and interactions between factors and their welfare outcomes and so identify optimum combinations of measures in future welfare assessments.

14. The EFSA Scientific Opinions on the welfare of dairy cows did not overlook any of the main hazards that were identified during the development of the Welfare Quality® protocol. However the EFSA Scientific Opinions did not deal with positive emotional states, unlike the Welfare Quality® project.

15. The Welfare Quality® protocol provides information on the majority of the welfare outcomes of the main hazards identified in the EFSA Scientific Opinions. However the limited time available during a single short visit means that there may not be sufficient behavioural observations in the Welfare Quality protocol to address some of the adverse effects identified in the EFSA Opinions e.g. time constraints on behaviour, behavioural disruption and thermal discomfort.

16. There are an increasing number of automatic recording systems that could feasibly be used by some farmers to gather data on animal-based measures that are otherwise too time consuming or difficult to gather.

17. The negative welfare outcomes of housing-related hazards, such as deficiencies in cubicle or tie-stall systems or insufficient opportunity for exercise and social interaction (tie stalls) cannot easily be prevented through short-term management.

18. The extent to which the negative effect of hazards arising from genetic selection for high milk yield without sufficient consideration for factors related to fitness (e.g. reduced productive life, infertility) that can be prevented through short-term management is extremely limited.

19. The attitudes of those involved and the ability to implement change are important with regard to the extent to which negative welfare outcomes can be prevented by management-related change. Even potentially easy management changes in various husbandry systems (e.g. provision of adequate bedding), may not be implemented in practice if the responsible person is not able or not willing to make the change.

20. The value of using animal-based measures taken at the slaughterhouse, to assess welfare on farm or during transport, depends on there being traceability of individual animals

21. Taking an adequate array of measures, in particular animal-based measures, requires specific training and competence.

22. At present, some welfare outcomes are difficult to quantify (e.g. pain associated with injury, exhaustion associated with prolonged high metabolic demand). Others can be quantified (e.g. lameness, length of productive life) but there are inconsistencies of definition and measurement.

RECOMMENDATIONS

1. Combinations of animal- and non-animal-based measures should be appropriate to meet the specific objectives of the assessment (e.g. legislation, management support, compliance with a quality assurance scheme).

2. The selection of animal-based measures or factors most important and appropriate to the objectives of an assessment is a critical step and should be based on scientific evidence.

3. Animal-based measures should be used wherever possible as they are the best indicators of dairy cow welfare. The validity, reliability and feasibility of the measure should be known before it is used. Non-animal-based measures may be used when they are good predictors of welfare as indicated by animal-based measures, and when they are more efficient as a means to safeguard the welfare.

4. The first stage in any programme to assess the welfare of dairy cows should employ a range of animal-based measures that highlight the most important problems, while ensuring that no major criterion of welfare is overlooked.

5. The development and implementation of automatic data recording systems for animal-based measures should be encouraged, as well as information on appropriate analyses and interpretation of the collected data to allow the early detection of potential problems.

6. Research is needed to develop new ways to identify and quantify the complex links between (input) factors and welfare outcomes (consequences). This research would help in the choice of optimum combinations of measures for future welfare assessments. Such analyses will require access to large data sets.

7. There should be collaboration between farmers, breeding companies and building engineers to prevent negative outcomes of less easily managed hazards such as those related to genetics and housing.

8. Herd monitoring (and surveillance) programmes should be implemented within the dairy industry using a range of appropriate animal-based measures as benchmarks in order to document welfare changes over time.

9. Recommendations in codes of practice or laws related to animal welfare should, when possible, be phrased directly in terms of the responses of the animal or the effects on the animal (i.e. the outcome), so that the extent to which the recommendation has been fulfilled can be assessed using the appropriate animal-based measure.

10. There should be training for farmers and their advisers concerning easily manageable hazards, that affect welfare, such as those related to nutrition, feeding and daily routines, in order to prevent their negative consequences.

11. For the purposes of animal welfare risk assessment, better use should be made of the systems, which are already established in the EU legislation, for tracing the origin of all individual cows when they are moved from farm to farm or from farm to slaughterhouse. This would facilitate further analysis of animal-based welfare outcome indicators and to guide any subsequent actions.

12. The systematic assessment of dairy cow welfare using animal-based measures, including inspection of records, measures recorded automatically or derived from veterinary procedures, should be made by competent persons.

13. There should be both initial and ongoing training of animal welfare assessors to ensure valid and reliable welfare assessment.

14. There is a need to develop improved methods for quantitative or semi-quantitative measurement of some welfare outcomes (e.g. pain associated with injury, exhaustion associated with prolonged high metabolic demand) and more consistent methods for quantifying some welfare outcome measures (e.g. locomotion score, productive life).

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146

APPENDICES

149 **APPENDIX 1**

150 The 105 recommendations considered in the EFSA Scientific Opinion on the welfare of dairy cows
151 (EFSA, 2009b) with suggested animal-based and non-animal-based measures that could be used to
152 ensure the fulfilment of the recommendations. When the measure has been described in detail in the
153 Welfare Quality® dairy cow protocol (Welfare Quality®, 2009) the reference number (e.g.
154 WQ:6.1.3.1) is given together with the name of the measure so that more information can be found.
155 The letter 'H' after the recommendation refers to the fact that it was considered of high importance in
156 the EFSA Opinion. An abbreviated version of this large table is presented as Tables 1-7 in the
157 Scientific Opinion and a list of all the animal-based measures included in this table is given in
158 Appendix 2. Blank rows originally contained a recommendation for further research and were
159 therefore not included in the abbreviated list.
160

	Recommendations	Animal-based measures	Non-animal-based measures
1.	The genetics of dairy cattle should be taken into account when designing housing and management methods for these animals. H	See Table 2: housing and equipment	See Table 2: housing and equipment
2.	In order to improve dairy cow welfare there is an urgent need to promote changes in the criteria used for genetic selection in the dairy industry. These changes should result in animals in which there are fewer demands on their mechanism of adaptability, less lameness, less mastitis, less reproductive disorder and less metabolic disorder. H	Measures of length of productive life (e.g. changes in mortality and culling rate, age distribution within herd) Outcome indicators for lameness, mastitis, reproductive and metabolic disorders (Tables 1, 4, 5) *NB: It is not possible to assess the overall impact of genetics at the farm or national level from measures made on single visits to individual farms* WQ:6.1.3.1 (Absence of injuries: lameness) WQ:6.1.3.2 (Absence of disease: vulvar discharge, milk somatic cell count, mortality, downer cows)	Record of sire selection in relation to welfare indicators (lameness, mastitis, reproductive and metabolic disorders)
3.	Breeding selection objectives for dairy cattle should include resistance to mastitis, lameness and other diseases. H	Measures of length of productive life (e.g. changes in mortality and culling rate, age distribution within herd) Outcome indicators for lameness, mastitis, reproductive and metabolic disorders (Tables 1, 4, 5) WQ:6.1.3.1 (Absence of injuries: lameness) WQ:6.1.3.2 (Absence of disease: vulvar discharge, milk somatic cell count, mortality, downer cows)	Record of sire selection in relation to welfare indicators (lameness, mastitis, reproductive and metabolic disorders)

4.	In order to improve dairy cow welfare, high weight should be given to the full range of fitness and welfare traits, even when these may conflict with selection for milk yield. H	Most animal-based measures WQ: All WQ animal-based measures	Record of sire selection in relation to welfare indicators
5.	In order to sustain a high milk yield in dairy cattle without associated poor welfare, the prevention of excessive loss of body condition in early lactation should be one of the objectives of genetic selection.	Measures of nutritional status WQ:6.1.1.1 (Absence of prolonged hunger: body condition score)	Record of sire selection in relation to welfare indicators
6.	In order to avoid poor welfare, such as that associated with reproductive disorders and loss of robustness, the breeding procedures for dairy cattle should be designed to reduce inbreeding. H		Records of sire and dam selection
7.	A multi-trait selection programme in which health, fertility and welfare traits are included in the breeding objectives is recommended	Most animal-based measures WQ: All WQ animal-based measures	Record of sire selection in relation to welfare indicators
8.			
9.	Wherever transgenesis or cloning procedures are carried out on dairy cattle, any effects of the procedures and of any genetic change on the welfare of the animals should be evaluated using an appropriate range of animal welfare indicators. The results of such welfare evaluation studies should be taken into account when considering whether or not to produce or farm such animals. H	Evidence of pain, distress and lasting harm associated with the processes themselves using an appropriate range of animal welfare indicators for the expected consequences of transgenesis (see Guidance on the risk assessment of food and feed from genetically modified animals including animal health and welfare aspects, (EFSA, 2012c)). WQ: All WQ animal-based measures	
10.	All dairy cattle should be fed a diet that provides sufficient energy, nutrients and dietary fibre to meet the metabolic requirements in a way that is consistent with digestion. When diet is changed there should be carefully controlled transition feeding in order to prevent poor welfare in the cattle. H	Measures of nutritional status Metabolic profile (e.g. βOHB) Rumen status Faeces consistency Milk composition (e.g. fat/protein) Fertility records Laminitis Measures of feed intake Incidence of milk fever Incidence of ketosis WQ:6.1.1.1 (Absence of prolonged hunger: body condition score)	Diet composition Feeding strategy

11.	Feeding systems should allow every individual cow to meet her needs for quantity and quality of feed	Measures of nutritional status Metabolic profile (e.g. βOHB) Rumen status Faeces consistency Milk composition (e.g. fat/protein) Fertility records Laminitis Measures of feed intake Neck lesions Behaviour at feeding time WQ:6.1.1.1 (Absence of prolonged hunger: body condition score) WQ:6.1.4.1 (Expression of social behaviours: agonistic behaviour)	Inspection of feeders and feed barriers Feeding strategy Number of feeding places per animal
12.	A water supply mechanism which allows a cow to put its mouth down into water should be provided. H	Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test) Observation that cows do put their mouths into the water	WQ: Inspection of water points. WQ:6.1.1.2 (Absence of prolonged thirst: water provision, water flow, functioning of water points)
13.	Where water troughs are provided, the number and position should be such that the animals do not need to wait too long or to compete for water. H	Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test) Waiting and agonistic behaviours at water points WQ:6.1.4.1 (Expression of social behaviours: agonistic behaviour)	Location of water points WQ: Inspection of water points. WQ:6.1.1.2 (Absence of prolonged thirst: water provision)
14.	Dairy cows should be provided with drinking water whatever their diet. This water should be in sufficient quantity to prevent any dehydration and should be free from repellent odour and taste, harmful infectious agents, toxic substances and contaminants that can accumulate in body tissue or be excreted in milk. H	Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test) Behavioural evidence that cows are drinking Water intake Toxic substance and metabolites in milk body tissue, clinical signs of intoxication	Inspection of water points Analysis of water source WQ: Inspection of water points. WQ:6.1.1.2 (Absence of prolonged thirst: water provision, cleanliness of water points)
15.	Both indoors as well as outdoors, continuous access to water should be provided. Automatically regulated troughs and drinker bowls should be installed in the animal houses and farmyards. H	Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test) Behavioural evidence that cows are drinking Water intake	WQ: Inspection of water points. WQ:6.1.1.2 (Absence of prolonged thirst: water provision)
16.	Contamination of feed-stuffs with noxious substances at source or in storage should be avoided	Animal reluctant to eat provided feed Animals leave large feed among feed in troughs Cud spitting - rumen bolus in and around feed troughs Toxic substance and metabolites in milk body tissue, clinical signs of intoxication Indicators of toxaemia WQ:6.1.1.1 (Absence of prolonged hunger: body condition score, very lean animals)	Feed analysis (macroscopic, lab analysis)

17.	Where feedstuffs are preserved, any drying, ensiling or storage should be properly carried out	Animal reluctant to eat provided feed Animals leave large feed among feed in troughs Cud spitting - rumen bolus in and around feed troughs Toxic substance and metabolites in milk body tissue, clinical signs of intoxication Indicators of toxaemia WQ:6.1.1.1 (Absence of prolonged hunger: body condition score, very lean animals)	Feed analysis (macroscopic, lab analysis)
18.	Concentrate feeding facilities on dairy farms should be adequately maintained and diets carefully balanced so as to maintain optimal ruminal fermentation and to minimise negative energy balance. H	Measures of nutritional status Metabolic profile (e.g. βOHB) Rumen status Faeces consistency Milk composition (e.g. fat/protein) Fertility records Laminitis Measures of feed intake Neck lesions Behaviour at feeding time WQ:6.1.1.1 (Absence of prolonged hunger: body condition score) WQ:6.1.4.1 (Expression of social behaviours: agonistic behaviour)	Inspection of feeders Feeding strategy Number of feeding places per animal
19.	Strategies for feeding and management of the dry cow should be designed to prevent metabolic disorders, such as parturient paresis (milk fever) which has an acute severe effect on animal welfare. H	Measures of nutritional status Metabolic profile (e.g. βOHB) Rumen status Faeces consistency Milk composition (e.g. fat/protein) Fertility records Laminitis Measures of feed intake Incidence of milk fever Incidence of ketosis WQ:6.1.1.1 (Absence of prolonged hunger: body condition score, very fat animals)	Diet composition Feeding strategy Feed space and availability (feeding time and frequency)
20.	Cubicles and tie-stalls should be designed in such a way that the forward movement of the body of the cow is not thwarted when changing position from lying to standing. H	Difficulties in changing position (standing up and lying down behaviour) Time spent standing Time spent lying down Lying in passage Skin lesions Hock, knee and skin lesions, and swellings WQ:6.1.2.1 (Comfort around resting: time needed to lie down, animals colliding with housing equipment during lying down)	Cubicle dimensions and design Arrangement of neck rail or brisket board

21.	Where cubicles are used, they should be wide enough, in relation to the size of the cows, to minimise any movement difficulties or teat trampling. H	Difficulties in changing positions (standing up and lying down behaviour) Time spent standing Time spent lying down Shifting weight from one foot to another Posture of cow in cubicle (cows lying with legs extended to another cubicle) Teat injuries Lying in passage Hock, knee and skin lesions, and swellings Colliding with equipment when standing or lying down WQ:6.1.2.1 (Comfort around resting: time needed to lie down, animals colliding with housing equipment during lying down, animals lying partly or completely outside the lying area) WQ:6.1.3.1 (Absence of injuries: integument alterations)	Cubicle dimensions and design
22.	Cubicles which force the cow to stand up with the front legs first should not be used. H	Getting up with front legs first Dog sitting Colliding with equipment when standing or lying down WQ:6.1.2.1 (Comfort around resting: time needed to lie down, animals colliding with housing equipment during lying down) WQ:6.1.3.1 (Absence of injuries: lameness)	Cubicle dimensions and design Arrangement of neck rail or brisket board

23.	Cubicle width should be at least 1.8 times cow hip width. H	Difficulties in changing positions (standing up and lying down behaviour) Time spent standing Time spent lying down Shifting weight from one foot to another Posture of cow in cubicle (cows lying with legs extended to another cubicle) Teat injuries Lying in passage Hock, knee and skin lesions, and swellings Colliding with equipment when standing or lying down WQ:6.1.2.1 (Comfort around resting: time needed to lie down, animals colliding with housing equipment during lying down, animals lying partly or completely outside the lying area) WQ:6.1.3.1 (Absence of injuries: lameness) WQ:6.1.3.1 (Absence of injuries: integument alterations)	Cubicle dimensions and design
24.	In cubicle houses there should be at least as many cubicles as there are cows in the house. H	Lying in passage Agonistic behaviours (e.g. chasing-up from cubicles) Time spent standing Time spent lying down Hock, knee and skin lesions, and swellings WQ:6.1.2.1 (Comfort around resting: animals lying partly or completely outside the lying area) WQ:6.1.3.1 (Absence of injuries: lameness)	Number of cubicles per animal
25.	In cubicle houses, injuries to the cows should be monitored and the cubicles modified or replaced, if repeated injuries occur because of poor design. H	Difficulties in changing positions (standing up and lying down behaviour) Time spent standing Time spent lying down Shifting weight from one foot to another Posture of cow in cubicle (cows lying with legs extended to another cubicle) Teat injuries Lying in passage Hock, knee and skin lesions, and swellings Colliding with equipment when standing or lying down WQ:6.1.3.1 (Absence of injuries: integument alterations)	
26.			

27.	Cubicle design should be such that no standing, lying or defecation movement is difficult for a cow and should not cause injuries to the cow	Difficulties in changing positions (standing up and lying down behaviour) Time spent standing Time spent lying down Shifting weight from one foot to another Posture of cow in cubicle (cows lying with legs extended to another cubicle) Teat injuries Lying in passage Hock, knee and skin lesions, and swellings Colliding with equipment when standing or lying down Difficulty in adopting defecation position. WQ:6.1.2.1 (Comfort around resting: time needed to lie down, animals colliding with housing equipment during lying down) WQ:6.1.3.1 (Absence of injuries: lameness) WQ:6.1.3.1 (Absence of injuries: integument alterations)	Cubicle dimensions and design
28.	All cubicles for dairy cattle should be long enough and have an appropriate neck rail positioning to enable each animal to stand comfortably with all four feet in front of the rear kerb	Difficulties in changing positions (standing up and lying down behaviour) Time spent standing Time spent lying down Shifting weight from one foot to another Posture of cow in cubicle (cows lying with legs extended to another cubicle, cows lying diagonally) Teat injuries Lying in passage Hock, knee and skin lesions, and swellings Colliding with equipment when standing or lying down Hind legs in cubicle passage WQ:6.1.3.1 (Absence of injuries: integument alterations) WQ:6.1.2.1 (Comfort around resting: time needed to lie down, animals colliding with housing equipment during lying down, animals lying partly or completely outside the lying area) WQ:6.1.3.1 (Absence of injuries: integument alterations)	Cubicle dimensions and design Arrangement of neck rail or brisket board

29.	The feeding area should be designed in such a way and with sufficient space that all cows can feed with minimal aggression or other interference. In loose-house systems, when food is not *ad libitum*, there should be sufficient space at the food source for all cows to feed at the same time. H	Measures of nutritional status Metabolic profile (e.g. βOHB) Rumen status Faeces consistency Milk composition (e.g. fat/protein) Fertility records Laminitis Measures of feed intake Incidence of milk fever Incidence of ketosis Behaviour at feeding time Competition and queuing behaviour for food Cows can all feed at the same time when food is not *ad libitum* WQ:6.1.1.1 (Absence of prolonged hunger: body condition score, very fat animals) WQ:6.1.4.1 (Expression of social behaviours: agonistic behaviour)	Design and dimensions of feeding areas Feed availability (feeding time and frequency)
30.	Space allowance in walking areas for dairy cows should be such that cows can pass one another easily. This requires at least consideration of physical space for two cows to pass (e.g. feeding alley: one cow length plus two cow shoulder widths)	Difficulties in moving around building (e.g. reluctance to move) Slipping and falling Agonistic behaviour WQ:6.1.4.1 (Expression of social behaviours: agonistic behaviour)	Design and dimensions of cubicle houses and straw yards
31.	The design of cubicle houses and straw yards should allow all the cattle to have access to lying, feeding and drinking areas without danger of injury or of difficulty with social interactions	Difficulties in moving around building (e.g. reluctance to move) Slipping Agonistic behaviour Cows can all feed at the same time when food is not *ad libitum* Skin lesions Hock, knee and skin lesions, and swellings WQ:6.1.2.1 (Comfort around resting: animals colliding with housing equipment during lying down) WQ:6.1.3.1 (Absence of injuries: integument alterations) WQ:6.1.4.1 (Expression of social behaviours: agonistic interactions)	Design and dimensions of cubicle houses and straw yards (e.g. no dead end)
32.	The tie length and tie-stall design should allow the cow to easily reach food and water and to lie down and stand up without difficulties showing normal behavioural pattern	WQ:6.1.2.1 (Comfort around resting: time needed to lie down, animals colliding with housing equipment during lying down) WQ:6.1.3.1 (Absence of injuries: integument alterations)	Design and dimensions tie-stalls

33.	Housing design and ventilation should be able to provide air speeds around housed animals in hot summer conditions (for example, more than 26 °C) of at least 0.6 m/s. H	Sweating, increased body temperature Water intake Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test) Feed intake	Temperature/humidity index Measures of ventilation inlet and outlet
34.	Cows outdoors should be provided with shelter from excessive solar radiation in the summer, wind and precipitation during cold periods	Sweating, increased body temperature Water intake Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test) Feed intake Signs of cold stress, such as huddling (individuals in close proximity to one another in order to reduce heat loss), shivering Attempts to seek shelter Posture	Presence of shelter
35.	At very low temperatures, housed dairy cows should be protected from conditions that may cause frost-bite or other tissue damage. Particular attention should be given to minimising direct heat loss from the udder to a cold floor	Frost bite on teats and ears Reluctance to lie down Limited mobility	Presence of shelter
36.	Dry cows should be kept in good conditions. These need not be the same as those used for cows during the milking period and can include the possibility for sufficient movement to prevent problems listed elsewhere (refers to many chapters). H	All indicators not specific to lactation, including low levels of locomotion, head held low as indicator of depression	
37.	Gas concentrations in dairy cow houses should not exceed 10 ppm ammonia, H_2S as a measurable amount (e.g. 0.5 ppm), 3,000 ppm carbon dioxide. H	Animals coughing Watery eyes Respiratory distress and collapse WQ:6.1.3.2 (Absence of disease: coughing, nasal discharge, ocular discharge, hampered respiration)	Gas (ammonia, H_2S, carbon dioxide) concentration
38.	Care should be taken not to stir manure or slurry containers in a way that increases H_2S or NH_3 to harmful levels in cattle buildings	Animals coughing Watery eyes Respiratory distress and collapse WQ:6.1.3.2 (Absence of disease: coughing, nasal discharge, ocular discharge, hampered respiration)	Gas (H_2S or NH_3) concentration
39.	When distinct activity of the cows is required during night time, a light intensity of more than 30 lux is required	Inability to navigate adequately or reduced locomotion at night	Light intensity
40.			

41.	The housing of dairy cows should be designed in a way so that they can lie down comfortably in order to get the amount of rest, lying and ruminating that they need. All cows should be able to lie down at the same time	Lying in passage Difficulties in changing positions (standing up and lying down behaviour) Chasing up behaviour, interrupted lying WQ:6.1.2.1 (Comfort around resting: time needed to lie down, animals colliding with housing equipment during lying down, cleanliness) WQ:6.1.4.1 (Expression of social behaviours: agonistic behaviour)	Design and dimensions housing sytem
42.	Stall and cubicle design should not affect the normal movement pattern of cows when lying down or getting up	Difficulties in changing positions (standing up and lying down behaviour) Time spent standing Time spent lying down Shifting weight from one foot to another Posture of cow in cubicle (cows lying with legs extended to another cubicle) Teat injuries Lying in passage Hock, knee and skin lesions, and swellings Colliding with equipment when standing or lying down WQ:6.1.2.1 (Comfort around resting: time needed to lie down, animals colliding with housing equipment during lying down)	Cubicle dimensions and design
43.	Cows or heifers kept in buildings should be provided with an area bedded with sufficient, dry, compressible, non-slippery material that does not lead to skin lesions	Hock, knee and skin lesions, and swellings Time spent lying down Cleanliness of animals high up on legs and on back WQ:6.1.2.1 (Comfort around resting: cleanliness) WQ:6.1.3.1 (Absence of injuries: integument alterations)	Number of cubicles
44.	Hock, knee and skin lesions should be used as an indicator of the quality of bedding for dairy cattle	Hock, knee and other skin lesions WQ:6.1.3.1 (Absence of injuries: integument alterations)	
45.	Dairy cattle should be housed so that they can walk without having to change their normal gait or speed because of slippery or bad flooring, or bad design of the housing system. H	Abnormal walking movement Slipping and falling Agonistic behaviours Foot lesions (claw and skin) Leg injuries and disorders associated with slipping. Measures of lameness WQ:6.1.3.1 (Absence of injuries: lameness)	Floor surface, dimensions of walking area, depth of slurry

46.	Systems of husbandry and management should involve a minimum time of restricted movement in order that all dairy cows are able to meet their need to show certain behaviours, such as grooming, social interaction and exercise	Head lowered for long periods as an indicator of depression Inadequate grooming behaviour, Abnormal social interaction and exercise	Presence of tethered animals WQ:6.1.2.3 (Ease of movement: presence of tethering, access to outdoor loafing area or pasture)
47.	While tie-stall use continues, cows should have daily exercise that involves walking freely inside or outside (except where there are adverse climatic conditions) and also the freedom to carry out other behaviours such as grooming	Head lowered for long periods as an indicator of depression Difficulties in changing position (standing up and lying down behaviour) due to skeletal and joint disorders Inadequate grooming behaviour, including excessive grooming of the front of the body Abnormal social interaction and exercise	Access to exercise area WQ:6.1.2.3 (Ease of movement: presence of tethering, access to outdoor loafing area or pasture)
48.	Currently there is only a limited amount of scientific data linking the period per day of being tied in a tie-stall to levels of disease and overall impact on welfare, so this should be studied.	Difficulties in changing position (standing up and lying down behaviour) Grooming behaviour in different parts of the body Abnormal social interaction and exercise Absence of normal range of resting postures	
49.	Minority Opinion: dairy cattle should not be routinely kept in tie-stalls as a housing system	Difficulties in changing position (standing up and lying down behaviour) Grooming behaviour in different parts of the body Abnormal social interaction and exercise Absence of normal range of resting postures	Absence of tethers; and evidence that housing is designed for free movement (e.g. free stalls of straw yards) Access to pasture or other outdoor area Tethered animals WQ:6.1.2.3 (Ease of movement: presence of tethering)
50.	When possible, dairy cows and heifers should be given access to well-managed pasture or other suitable outdoor conditions, at least during summer time or dry weather**.** H	Measures of lameness WQ:6.1.3.1 (Absence of injuries: lameness) WQ:6.1.3.2 (Absence of disease: vulvar discharge, milk somatic cell count, mortality, downer cows) WQ:6.1.3.2 (Absence of disease: coughing, nasal discharge, ocular discharge, hampered respiration)	Absence of tethers; and evidence that housing is designed for free movement (e.g. free stalls of straw yards) Records being kept for the number of days cows and heifers are let out to pasture Access to pasture or other outdoor area WQ:6.1.2.3 (Ease of movement: access to outdoor loafing area or pasture) WQ:6.1.4.2 (Expression of other behaviours: access to pasture)
51.	Dairy cattle should not be caused to stand or walk for prolonged periods on concrete floors or floors that are wet or covered in slurry. H	Foot lesions (claw and skin) Leg injuries and disorders associated with slipping Measures of lameness Animals standing in water/slurry WQ:6.1.3.1 (Absence of injuries: lameness)	Time in collecting yard

52.	Electric cow trainers should not be used. H	Skin lesions	Presence of electric cow trainers
53.	Precautions should be taken to minimise the risks of stray voltages in dairy cattle housing	Aversion behaviour associated with being shocked	Stray voltage
54.	The maintenance of milking equipment and all milking procedures should be carried out in accordance with relevant guidelines	Stopping and turning around behaviour Kicking off clusters Evidence of mastitis, teat injuries Avoidance of humans Residual milk Time to enter milking area WQ:6.1.3.2 (Absence of disease: milk somatic cell count, teat injuries) WQ:6.1.4.3 (Good human-animal relationship: avoidance distance)	Records of milking machine maintenance
55.	Milking equipment should be designed, constructed, managed, cleaned and disinfected so that the risk of injury, pain and disease in dairy cows is minimised. H	Time to enter milking area Stopping and turning around behaviour Kicking off clusters Evidence of mastitis, teat injuries Avoidance of humans Residual milk WQ:6.1.3.2 (Absence of disease: milk somatic cell count, teat injuries) WQ:6.1.4.3 (Good human-animal relationship: avoidance distance)	Records of milking machine maintenance
56.	Milking equipment should be checked and maintained at least once every six months	Time to enter milking area Stopping and turning around behaviour Kicking off clusters Evidence of mastitis, teat injuries Avoidance of humans Residual milk WQ:6.1.3.2 (Absence of disease: milk somatic cell count, teat injuries) WQ:6.1.4.3 (Good human-animal relationship: avoidance distance)	Records of equipment checks
57.	Milking equipment/machines should be used and maintained to manufacturers' specifications to avoid trauma to the teat and udder	Time to enter milking area Stopping and turning around behaviour Kicking off clusters Evidence of mastitis, teat injuries Avoidance of humans Residual milk WQ:6.1.3.2 (Absence of disease: milk somatic cell count, teat injuries) WQ:6.1.4.3 (Good human-animal relationship: avoidance distance)	Records of equipment checks

58.	Cleaning of udders should take full account of the risk of transmission of pathogens. H	Cleanliness of udder (especially teat end) Evidence of mastitis (e.g. clots and blood in milk, udder and teat inflammation and ulcers, somatic cell counts) WQ:6.1.3.2 (Absence of disease: milk somatic cell count)	
59.	The persons who are milking cows should behave calmly and consistently towards cows during collection of cows, milking and post-milking movement	Irregularity in daily milk yield associated with personnel change Reluctance to enter milking parlour Measures of avoidance of people and approach to people, especially milking personnel Residual milk WQ:6.1.4.3 (Good human-animal relationship: avoidance distance)	
60.	Waiting times in collecting or milking areas before milking for each cow should be short and never more than one hour	Measure of time that cows are waiting WQ:6.1.3.1 (Absence of injuries: lameness)	
61.	Cows should be allowed to have access to food and water independently of visiting the milking robot, except for initial training purposes. **H**	Non-milking visits to robot Duration of meals	Presence of free traffic situation (open gates to feeding area and water points that do not force animals to pass through the robot)
62.	The design of robot milking systems should not restrict the cow's access to a sufficient amount of a balanced diet. During the grazing season this may include access to pasture.	Measures of nutritional status Metabolic profile (e.g. βOHB) Rumen status Faeces consistency Milk composition (e.g. fat/protein) Fertility records Laminitis Measures of feed intake Incidence of milk fever Incidence of ketosis WQ:6.1.1.1 (Absence of prolonged hunger: body condition score, very fat animals)	Presence of free traffic situation (open gates to feeding area and water points that do not force animals to pass through the robot)
63.	Robotic milking systems should be carefully adjusted and checked each day. H	Reluctance to enter the robot unit Udder injuries, Clinical evidence of mastitis	Standard operation procedure for checking of robot
64.	All cows on a robotic milking system should be inspected twice per day		Records of inspection
65.	Husbandry practices should avoid regrouping of dairy cows as far as possible in order to facilitate continuation of long-lasting social bonds, avoid frequent disruption and provide social stability	Aggression, submissiveness, behavioural indicators of fear, injury resulting from fighting, lowered head as indicator of depression, avoidance of social contact Drop in milk yield WQ:6.1.4.1 (Expression of social behaviours: agonistic interactions)	

66.	There should be development and implementation of housing design enabling selective, yield-matched feeding within a herd (e.g. by selection doors) and thus avoiding regrouping	Aggression, submissiveness, behavioural indicators of fear, injury resulting from fighting, lowered head as indicator of depression, avoidance of social contact Drop in milk yield WQ:6.1.4.1 (Expression of social behaviours: agonistic interactions)	
67.	If social mixing of dairy cows is unavoidable, stress should be reduced by providing larger space allowance during grouping in buildings or on pasture	Aggression, submissiveness, behavioural indicators of fear, injury resulting from fighting, lowered head as indicator of depression, avoidance of social contact Drop in milk yield WQ:6.1.4.1 (Expression of social behaviours: agonistic interactions)	WQ:6.1.4.2 (Expression of other behaviours: access to pasture)
68.			
69.	Dairy cows calving in buildings should be moved to individual calving pens with some contact with other cows before calving in order to minimise welfare problems. H	Cows interfering with other cows during calving Calves not accepted by cows Body conditions of calves, neonatal disease and calf mortality	Number of calving pens available according to seasonality of calving Location of calving pens in close proximity to other cows/allowing contact with other cows
70.	Dairy cow housing and management should ensure that there are sufficient calving pens. H	Cows interfering with other cows during calving Calves not accepted by cows Body conditions of calves, neonatal disease and calf mortality	Number of calving pens available according to seasonality of calving Location of calving pens in close proximity to other cows/allowing contact with other cows
71.	At separation, cow and calf should be placed so that they cannot hear or see each other When the cow has nursed her calf for the whole milk period or when she has been a foster cow weaning plates on the muzzle of the calf should be used	Excessive cow bellowing High level of calf activity High levels of calf attempts to suckle	Weaning plates
72.			
73.			
74.	There should be systems for monitoring the prevalence and severity of lameness by scoring locomotion and foot lesions every 3 to 6 months in all dairy herds. Proper analysis of data from lameness monitoring should be integrated into subsequent farm management.	Measures of lameness Evidence of discomfort when standing (e.g. paddling) Foot lesions, such as sole ulcer, sole haemorrhage, white line separation Infectious conditions of claw and skin (e.g. digital dermatitis) WQ:6.1.3.1 (Absence of injuries: lameness)	Records of lameness and foot lesion

75.	Foot inspection with trimming as necessary should be carried out at intervals not greater than 6 months	Measures of lameness Measure of overgrown and misshapen hooves Evidence of discomfort when standing (e.g. paddling, resting a foot) Foot lesions, such as sole ulcer, sole haemorrhage, white line separation Infectious conditions of claw and skin (e.g. digital dermatitis) WQ:6.1.3.1 (Absence of injuries: lameness)	Records of foot trimming
76.	There should be attention to foot hygiene of dairy cattle on a weekly basis, followed by proper treatment, as necessary	Lameness Evidence of discomfort when standing (e.g. paddling, resting a foot) Foot lesions, such as sole ulcer, sole haemorrhage, white line separation Infectious conditions of claw and skin (e.g. digital dermatitis) WQ:6.1.3.1 (Absence of injuries: lameness)	
77.	Because of the high risk of lameness in dairy cattle all dairy farmers should implement a lameness prevention programme. H	Measures of lameness Measure of overgrown and misshapen hooves Clinical signs of infection in the hooves region WQ:6.1.3.1 (Absence of injuries: lameness)	Records of foot inspection Facilities for foot bathing and foot inspection
78.	Lameness should be prevented, although in practice this can rarely be achieved at present. Clinical cases should be given proper veterinary care. When systematic monitoring indicates an increasing prevalence, appropriate corrective measures should be taken at the herd level. On farms with a high prevalence of recognisable locomotor difficulties (e.g. approaching 10 %) there should be improvement of housing conditions, genetic strain and management practices. H	Measures of lameness Evidence of discomfort when standing (e.g. paddling, resting a foot) Foot lesions, such as sole ulcer, sole haemorrhage, white line separation Infectious conditions of claw and skin (e.g. digital dermatitis) WQ:6.1.3.1 (Absence of injuries: lameness)	Records of treatments administered
79.			
80.	Pain relief should be provided during and after treatment for severe lameness. H	Weight removed from the affected hoof, by corrective trim or application of a block	Facilities for hospitalisation of severely lame cows Evidence of knowledge of how to carry out pain management procedures Records of provision for pain relief (e.g. use of analgesic, provision of improved bedding)

81.	Hoof-trimming should be carried out with care by professionally trained and certified personne.	Measure of overgrown, misshapen or incorrectly-trimmed hooves Lameness WQ:6.1.3.1 (Absence of injuries: lameness)	Licensed or training of hoof trimmer
82.	Pain management should be part of the treatment of clinical mastitis. H	Behavioural evidence of pain (e.g. hypersensitivity to touch on teat or udder, reluctance to move)	Records of evidence of materials for pain relief and training
83.	In order to reduce udder infections, a full programme of control measures should be implemented. For example, cleaning of milking equipment should be performed adequately by chemical, thermal and physical processes. The environment of the cow should be clean, dry and well ventilated.	Clinical evidence of mastitis, including fever and general malaise, teat and udder lesions and hypersensitivity and clots and blood in milk, udder and teat inflammation and ulcers, somatic cell counts WQ:6.1.2.1 (Comfort around resting: cleanliness of udder, flank/upper legs and lower legs) WQ:6.1.3.2 (Absence of disease: milk somatic cell count)	Record of programme for prevention and control of mastitis, including surveillance using bacteriological examinations and somatic cell counts, therapeutic strategies including the use of antimicrobials Records of programme for dry cow therapy, milking hygiene, culling policy
84.	To improve cow welfare, the prevalence of mastitis should be reduced by the treatment of clinical and subclinical disease, dry cow therapy, identification and elimination of carrier cows, prevention of transmission of infection from cow to cow or through the environment, and improvement of the immune system by minimising stress factors and by a controlled and nutritionally-balanced feed intake. H	Clinical evidence of mastitis, including fever and general malaise, teat and udder lesions and hypersensitivity and clots and blood in milk, udder and teat inflammation and ulcers, somatic cell counts WQ:6.1.3.2 (Absence of disease: milk somatic cell count)	Record of programme for prevention and control of mastitis, including surveillance using bacteriological examinations and somatic cell counts, therapeutic strategies, including the use of antimicrobials Records of treatments, dry cow therapy, milking hygiene, culling policy
85.	To reduce risk of dystocia, particularly at first calving, heifers should be inseminated after they reach the mature weight for the breed and only sires known to have low incidence of dystocia should be used to breed heifers. H	Dystocia WQ:6.1.3.2 (Absence of disease: dystocia)	Age at insemination or calving Records of sire selection Breeding value of sire calving ease
86.	Good hygiene should be provided at calving to reduce risk of genital infections	Records and evidence of genital infections Observation of vulvar discharge. WQ:6.1.3.2 (Absence of disease: vulvar discharge)	Records of hygiene procedure (e.g. appropriate management of cows with retained placenta)
87.			

88.	Regardless of housing system, herd health and biosecurity programmes, continuously adapted to the unique situations of each individual enterprise, should be in place to prevent introduction of disease and pathogens to the dairy herds and to control spread within the herd. H	Clinical signs of infectious diseases WQ:6.1.3.2 (Absence of disease: all measures)	Records of health and biosecurity programmes, and of cattle movement adapted to unique farm situation
89.	Biosecurity programmes should be supported by monitoring and documentation of diseases occurrence and variables like patterns of antibiotic resistance, and applied strategies for prevention and intervention should, when justified, be adapted along with new epidemiological information. H	Evidence of infectious- and production-related diseases WQ:6.1.3.2 (Absence of disease: all measures)	Recording system for biosecurity programmes, including routines for staff and visitors, health control programmes and treatment, including laboratory examinations of diseased animals adapted to a unique farm situation Evidence of requirements for the introduction of new heifers and bulls (e.g. disease free status) Presence of quarantine facilities Evidence of disease free status of artificial insemination centres used by the farm
90.	Measures for the early detection of disease should be in place and farmers and stockpersons should be well trained to recognise disease at early stages. Veterinary attention should be sought at early stages of disease.	Evidence of disease that should have been detected and treated earlier (e.g. severe lameness) WQ:6.1.3.1 (Absence of injuries: lameness) WQ:6.1.3.2 (Absence of disease: all measures)	Evidence of training Monitoring system for signs of disease
91.	Replacement stock should be sourced from specified disease-free herds or those of an equal or higher health status	Outbreak of disease resulting from introduced animals WQ:6.1.3.2 (Absence of disease: all measures)	Records of animal movements of quarantine and of management of newly introduced animals
92.	Cows should be inspected for disease daily and there should be extra checks around calving and the first three weeks of lactation		Records of inspection for disease Breeding records
93.	Hygienic precautions, especially at calving and at milking time, should be envisaged for reducing disease transmission	Evidence of mastitis, metritis and other infectious and production-related diseases WQ:6.1.3.1 (Absence of injuries: lameness) WQ:6.1.3.2 (Absence of disease: all measures)	Record of hygiene procedures
94.	Efforts should be made to minimise the transport of animals, in particular, between herds, and, when such transports are applied, special attention should be given to the reduction of associated risks of poor welfare and spread of infectious diseases. (See also previous Scientific Opinions). H	Evidence of infectious diseases WQ:6.1.3.2 (Absence of disease: all measures).	Records of animal movements of quarantine and of management of newly introduced animals
95.			

96.	Dairy farms should have facilities for severely ill or injured animals and such animals should be moved to these facilities as soon as possible. H		Presence of sick-pens and (separate) calving pens
97.	Facilities for sick animals with infectious diseases should not be used for calving. H		Presence of facilities and records of their use
98.	Any medication for dairy cattle should be used according to legislation, written codes of practice, veterinary prescription and manufacturer's advice	Chronic disorders after inappropriate treatment	Records of treatment procedures
99.	Antimicrobials should not be used as a replacement for good management, and the continuous implementation of preventive measures should be prioritised in order to avoid problems with antimicrobial resistance and associated bad welfare	Presence of antimicrobial resistant pathogens (e.g. in milk)	Records of usage of antimicrobials Herd health plan
100.	Hormonal treatments to improve fertility should not be used to compensate for deficits in management		Records of hormonal treatments and fertility (calving intervals, anoestrus, return to oestrus) Evidence of methods of oestrus detection Breeding records
101.	In order to improve welfare and production, young cattle should be given appropriate experience of human contact and all cattle should be handled calmly with gentle contact	Avoidance behaviour to humans WQ:6.1.4.3 (Good human-animal relationship: avoidance distance)	Observe human behaviour
102.	Stockpersons should receive training in animal management methods and animal welfare. H	Avoidance behaviour or aggression to humans, Increased reactivity to humans WQ:6.1.4.3 (Good human-animal relationship: avoidance distance)	Evidence of training courses taken by stockpersons
103.	Electric goads should not be used on cattle. H	Avoidance behaviour to humans WQ:6.1.4.3 (Good human-animal relationship: avoidance distance)	Evidence of electric goads on-farm
104.	Appropriate care of animals with systemic mastitis should include separation to adequate facilities with good bedding and management of toxaemia and pain. Veterinary advice should be sought. Also, antimicrobial treatments should be judicious so as to be effective, as well as to reduce the possibility of bacterial resistance. H		Presence of facilities Record of treatment and efficacy of treatment
105.	Cattle should be marked using micro-chips, freeze-branding or tags that involve small injuries. Hot-iron branding causes severe pain and should not be used. H	Evidence of marking methods Infections from marking	Tags or marking equipment on farm. Record of marking methods

106.	De-horning of heifers and cows should be avoided wherever possible and carried out only with the use of regional anaesthesia and analgesia. Disbudding when the animals are calves should be carried out, if horn removal is necessary, but anaesthesia and analgesia should be used. H	Presence of horns in groups of calves at the age limit above which disbudding cannot be carried out	Record of procedures and equipment for local anaesthesia and analgesia usage Evidence of veterinarian's work during disbudding or dehorning procedure Record of breeding polled cattle WQ:6.1.3.3 (Absence of pain induced by management procedures: disbudding/dehorning)
107.	The tails of cattle, including dairy cows, should not be docked. H	Docked tails observable	WQ:6.1.3.3 (Absence of pain induced by management procedures: tail docking)
108.	The placenta should be removed from the floor of the calving pen as soon as possible		Presence of placenta on floor
109.	Service of heifers should not occur until they reach 65 % of their expected mature weight to reduce potential for calving difficulty	Dystocia WQ:6.1.3.2 (Absence of disease: dystocia)	Record of age of calving Record of weight of heifer at first inseminations
110.	Dairy cattle should be handled carefully, for example, during milking, artificial insemination, service, embryo transfer, caesarean section, and normal calving	Avoidance of humans by animals Injuries associated with poor procedures WQ:6.1.4.3 (Good human-animal relationship: avoidance distance)	Observation of harsh treatment
111.	Downer cows should have food and water within easy reach, care should be taken to prevent spilling of water that would contact the cow and manual assistance should be offered at regular intervals to aid recumbent animals in their attempts to stand. If the prognosis is hopeless or very poor, then euthanasia on welfare grounds should be advised. H	Downer cows Evidence of wet coat in downer cows Evidence that cow can feed or drink water WQ:6.1.3.2 (Absence of disease: downer cows)	Presence of sick-pens Procedure for handling of downer cows Presence of decision rules for euthanasia of downer cows
112.	On-farm killing of downer cows or other cattle should be carried out only by the use of a humane method. H		Established procedure and equipment available for killing downer cows
113.	Pain management should be carried out in dairy cattle in such a way as to combine the reduction of pain and the prevention of possible hyperalgesia		Evidence and records of anaesthesia and analgesia usage (e.g. prior to severe hoof trimming and during calving)
114.	The risk assessment highlighted that pain management should be part of treatment of cows with acute mastitis	Behavioural evidence of pain (e.g. hypersensitivity to touch on teat or udder)	Records of pain management Records of evidence of materials for pain relief and training
115.			

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APPENDIX 2

The list of animal-based measures from Appendix 1 is collected into a single table to give an overview of the measures identified as being useful in order to ensure the fulfilment of the recommendations. It can be considered as a 'toolbox' of potential animal-based measures from which to select the most appropriate measures according to the specific objective of the assessment.

A very brief description of the animal-based measure is given if this is not immediately apparent. All the terms below are measures, even if most are described in broad terms (e.g. fertility records, metabolic profiles, feeding behaviour) to indicate the type of observation, measurement or record that can be used. In some cases, there can be some very specific animal-based measures (e.g. behavioural evidence that cows do put their mouth into the water) and this is because of the way that the recommendation was worded. They do not describe how the individual observations and measurements should be made or how they should be interpreted in the assessment of welfare outcomes (also called consequences in Figure 1).

In most cases, the observations and measures are made on individual animals and interpreted at the farm or group level (e.g. percentage of animals with hock lesions). It is expected that other animal-based measures will be identified in the future. The methodology for recording and interpreting these measures is based on published scientific evidence and sound clinical practice. The science that underpins most of these indicators (e.g. fertility records, metabolic profiles) is derived from a large number of original communications and it would be unhelpful to cite only a few. For the most part, therefore, it is suggested that readers seeking further details of methodology and interpretation make reference in the first instance to comprehensive review publications (e.g. Rushen et al., 2008; EFSA, 2009a; Welfare Quality®, 2009). Original communications are only quoted when they provide a self-sufficient account of methodology and interpretation.

The animal-based measures have been ordered according to how many times they were mentioned in Appendix 1. Nevertheless, how often a measure is proposed to address a recommendation does not give any indication of how good the measure is, or how important the welfare outcome. It is therefore only intended as an indication of a possible future approach to rank the usefulness of animal-based measures to address animal welfare areas of concern, such as those addressed in the EFSA recommendations (EFSA, 2009b).

Animal-based measures	Reference	Times mentioned in Appendix 1
Measures of lameness (e.g. gait scoring and mobility scoring records)	Welfare Quality® 6.1.3.1 EFSA (2009a) Chapter 9 Rushen et al. (2008), pp 23-28 Poursaberi et al. (2010)	18
Hock, knee and skin lesions, and swellings	Welfare Quality :6.1.3.1	13
Measures of mastitis (e.g. abnormal milk, udder inflammation, somatic cell counts, fever and general malaise and teat and udder hypersensitivity)	Welfare Quality® :6.1.3.2 EFSA (2009a), pp 151-155	13
Colliding with equipment when standing or lying down	Welfare Quality® :6.1.2.1	11
Teat injuries	Welfare Quality® :6.1.3.1 Rushen et al. (2008), pp 34-35	11
Agonistic behaviour (e.g. chasing-up from cubicles)	EFSA (2009a), pp 79-82 and Chapter 8 (social interaction) Rushen et al. (2008) Capdeville and Veissier (2001)	10
Evidence of discomfort when standing (e.g. resting a foot, shifting weight from one foot to another)	EFSA (2009a), p. 143 Leach et al. (2009) Chapinal et al. (2011)	10

Aggression to or avoidance of humans as an indicator of inappropriate human-animal interaction	Welfare Quality® (2009):6.1.4.3, EFSA (2009a), pp 164-171 Rushen et al. (2008), pp 233-237	9
Time spent lying down/Time spent standing	EFSA (2009a), pp 96-100 WQ:6.1.2.1 Ito et al. (2009)	9
Lying in passage – reflecting inadequate cubicle number or design	Welfare Quality® (2009): 6.1.2.1	8
Measures of feed intake (e.g. rumen fill)	EFSA (2009a), pp 60-61 Rushen et al. (2008), p. 17 Feeding time on pasture (Ueda et al., 2011)	8
Behavioural evidence of pain (e.g. hypersensitivity to touch on teat or udder, reluctance to move)	EFSA (2009a), pp 154-155	7
Measure of nutritional status (e.g. body condition score, as an indicator of how lean or fat the animal is)	Welfare Quality® (2009)	7
Difficulties in changing positions (e.g. abnormal standing up and lying down behaviour) including:	EFSA (2009a), pp 102-103	6
Evidence of infectious diseases	Welfare Quality® 6.1.3.2	6
Faeces consistency as a measure of gastro-intestinal health	Welfare Quality® (2009): 6.1.3.2	6
Metabolic profile, milk and blood sampling, as a measure of excessive tissue mobilisation/metabolic stress (e.g. serum concentrations of metabolites such as glucose, cholesterol, non-esterified fatty acids, blood urea nitrogen, creatinine, total proteins, albumin, globulin and minerals)	EFSA (2009a), p. 68	6
Posture of cow in cubicle (cows lying with legs extended to another cubicle, cows lying diagonally) as an indicator of discomfort and inappropriate cubicle design	EFSA (2009a), p. 97	6
Rumen status (e.g. as a measure of adequacy of diet composition/fibre content, such as rumen fill, rumen impaction)	EFSA (2009a), pp 56-57 Huxley and Whay (2006)	6
Fertility records (e.g. longer interval to onset of cyclicity postpartum, lower conception rate early in lactation) as an indicator of production stress	EFSA (2009a), pp 41-42 Phillips (2010) Hulsen (2008) Garcia et al. (2011)	5
Measures of milk composition (e.g. fat/protein) as an indicator of energy deficiency in early lactation	Heuer et al. (2000) Brand et al. (1996)	5
Downer cows	Welfare Quality :6.1.3.2 EFSA (2009a), p. 188	4
Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test) reflecting insufficient water intake		4
Foot lesions, such as sole ulcer, sole haemorrhage, white line separation, as measures of hoof health	EFSA (2009a), pp 147-149	4
Infectious conditions of claw and skin (e.g. digital dermatitis as measure of foot health)	EFSA (2009a), pp 141-143	4
Measure of water intake	EFSA (2009a), p. 62 Rushen et al. (2008), pp 226-227	4
Restricted social interaction and exercise	EFSA (2009a), p. 109	4
Stopping and turning round on way to	Phillips (2002)	4

milking area and kicking off clusters as indicators of fear and pain associated with the use of milking equipment and also of milking equipment function, time to enter milking area.		
Abnormal walking movement (e.g. slipping and falling)	EFSA (2009a9), pp 115-116 Rushen et al. (2008)	3
Animals coughing as a measure of air quality or disease	Welfare Quality 6.1.3.2 Ferrari et al. (2010)	3
Behaviour at feeding time (e.g. displacements, duration and frequency of meals as measures of access to feed, competition and queuing behaviour for food)	EFSA (2009a), pp 81-82 von Keyserlingk and Weary (2010)	3
Behavioural evidence that cows are drinking	Phillips (2002)	3
Cleanliness of the animals high up on legs and on back	Welfare Quality 6.1.2.1	3
Cleanliness of udder as an indicator of inadequate lying conditions and hygiene	Welfare Quality 6.1.2.1	3
Grooming behaviour in different parts of the body as an indicator of freedom of movement	EFSA (2009a), pp 75 and 78	3
Overgrown and misshapen hooves, reflecting lack of appropriate foot care		3
Abnormal getting up or sitting behaviour (e.g. getting up with front legs first, dog sitting)	EFSA (2009a), p. 103 EFSA (2009a), pp 101-102	2
Body conditions of calves, neonatal disease and calf mortality	Rushen et al. (2008), pp 22-23, 29-30 Andrews et al. (2004)	2
Body temperature as a measure of thermal comfort or disease	EFSA (2009a), p. 90 West (2003)	2
Calves not accepted by cows so calf does not receive colostrum	Broom and Fraser (1990)	2
Clinical measures of respiratory distress and collapse	Welfare Quality :6.1.3.2	2
Dystocia	Welfare Quality .6.1.3.2, EFSA (2009a), pp 181-185 Rushen et al. (2008), pp 29-30	2
Foot lesions (claw and skin)	EFSA (2009a), Chapter 9.6 (general foot lesions)	2
Frequency and duration of meals as an indicator of inadequate access to feed and water	Munksgaard et al. (2011)	2
Incidence of ketosis as a measure of metabolic stress, mainly during transition period	EFSA (2009a), pp 67-70 Radostits et al. (2007), p. 1661	2
Incidence of milk fever as an indicator of production stress	EFSA (2009a), p. 72 Radostits et al. (2007), p. 1626	2
Leg injuries and disorders associated with slipping	Welfare Quality :6.1.3.1	2
Measure of length of productive life (e.g. number of completed lactations, mortality and culling rates, age distribution within herd profitable lifetime index)	EFSA (2009a), p. 193 Welfare Quality :6.1.3.2 Mortality, Rushen et al. (2008), pp 22-23	2
Measures of heat stress (e.g. sweating)	EFSA (2009a), p. 90	2
Non-milking visits to robot as an indicator of access to feed and water	EFSA (2009a), pp 122-123 Stefanowska et al. (1999)	2
Observations of cows interfering with other	EFSA (2009a), pp 132-133	2

cows during calving which will cause disturbance and reduce colostrum intake		
Reluctance to enter the robot unit (e.g. stopping and turning around, as an indicator of fear and pain associated with the use of a milking robot)	EFSA (2009a), pp 121-124	2
Skin lesions	Welfare Quality :6.1.3.1	2
Watery eyes as an indicator of air quality or disease	Welfare Quality 6.1.3.2	2
Measures of toxaemia (e.g. toxic substance and metabolites in milk body tissue, clinical signs of intoxication		2
Docked tails observable	Welfare Quality® :6.1.3.3	1
Evidence of marking methods that cause pain (e.g. hot iron branding)	EFSA (2009a), pp 171-172	1
Injures and infections from ear tagging	EFSA (2009a), p. 172	1
Laminitis (acute laminitis) as an indicator of diet imbalance	EFSA (2009a), p. 141 Nocek (1997) Bergsten and Frank (1996)	1
Neck lesions for feeding		1
Observation that cows do put their mouths into the water as a measure of access to water	EFSA (2009a)	1
Presence of guaranteed specific infectious disease free health certificate as evidence of biosecurity		1
Presence of horns in groups of calves at the age limit above which disbudding cannot be carried out	Welfare Quality 6.1.3.3	1
Restricted range of resting postures	EFSA (2009a), pp 97-98	1
Udder injuries	Welfare Quality :6.1.3.1 Rushen et al. (2008), pp 34-35	1
Waiting and agonistic behaviours at water points	EFSA (2009a), pp 81-82 Lievaart and Noordhuizen (2011)	1
Weight removed from the affected hoof, by corrective trim or application of a block	Andrews et al. (2004)	1
Difficulty in adopting defecation position	EFSA (2009a) p 21,	1
Evidence of cold stress: huddling, shivering, attempts to seek shelter, posture, frost bite on teats and ears, reluctance to lie down, limited mobility	EFSA (2009a) pp 88-90	1
Evidence of pain, distress and lasting harm associated with the processes of transgenesis or cloning themselves using an appropriate range of animal welfare indicators for the expected consequences of transgenesis	EFSA, (2012)c	1

191

192 **APPENDIX 3**

193 Table comparing the 31 measures included in the Welfare Quality® dairy cow protocol (as described
194 in Section 1.1 of this Opinion and in Welfare Quality®, 2009) and the 55 main hazards from the EFSA
195 Scientific Opinion (EFSA, 2009c, d, e, f) obtained as described in Section 2.2.1. An 'X' in the cell
196 indicates that the adverse effect (outcome or consequence as described in Figure 1) arising from that
197 hazard (the hazard characterisation) can be covered by that particular measure in the Welfare Quality®
198 protocol. There is also a column indicating whether the hazard itself is addressed by the Welfare
199 Quality® protocol.

200

	Hazard category	Hazard description	Is hazard covered by Welfare Quality® protocols?	Hazard characterisation	Good feeding		Good housing			Good health																								Appropriate behaviour				
				Adverse effect	Absence of prolonged hunger	Absence of prolonged thirst	Comfort around resting	Thermal comfort	Ease of movement	Absence of injuries	Absence of disease																								Absence of pain induced by management procedures	Expression of social behaviours	Expression of other behaviours	Good human-animal relationship	Positive emotional state	
					Body condition score	Water provision	Cleanliness of water points	Water flow	Functioning of water points	Time needed to lie down	Animal colliding with housing equipment during lying down	Animals lying partly or completely outside the lying area	Cleanliness of udder, flank, upper leg and lower legs	No measure developed	Presence of tethering	Access to outdoor loafing area or pasture	Lameness loose housed animals	Lameness tied animals	Integument alterations	Coughing	Nasal discharge	Ocular discharge	Hampered respiration	Diarrhoea	Vulvar discharge	Milk somatic cell count	Mortality	Dystocia	Downer cows	Disbudding/dehorning	Tail docking	Agonistic behaviour	Access to pasture	Avoidance distance	Qualitative behaviour assessment	Total
1	**Genetics**	**High genetic potential for production due to selection ignoring other traits**	NO	Mastitis	X																					X												2
				Metabolic disorders	X																			X			X		X								4
				Reproductive disorders	X																		X				X										3

				Leg injuries, claw disorders, pain	X					X							X	X	X																			5
				Increased constraint on time available for activities																																			0
				Discomfort as a result of full udder								X																										X	2
2	**HOUSING**	**Being tied without exercise (3 months of grazing or zero-grazing)**	YES	Locomotion problems, behaviour disruption, frustration, social stress						X							X	X												X						X	5
3	**HOUSING**	**Inadequate bedding**	NO	SARA, ketosis, reduced fertility, pain	X																		X														2
				Leg injuries, claw disorders, pain	X					X							X	X	X																			5
				Too little rest, behaviour disruption and prevention, pain, thermal discomfort, fear						X		X					X	X																			X	5
				Systemic mastitis and trauma, including teat problems	X														X						X	X		X										5
4	**HOUSING**	**Inadequate floor in area where cows walk**	NO	Locomotion, injuries, claw and leg disorders, maintenance behaviour, reproduction, pain	X					X							X	X																				4
5	**HOUSING**	**Inadequate ventilation, inappropriate airflow, airspeed**	NO	Reduced feed intake, immunosuppression, less oestrus expression, reduced fertility, SARA, ketosis	X															X	X	X	X	X	X	X											8
6	**HOUSING**	**Inappropriate temperature, humidity**	NO	Dehydration, reduced feed intake, ketosis, SARA, reproductive failure	X																			X													2
				Thermal discomfort																																			0
7	**HOUSING**	**Lack of facilities for sick/injured animals**	NO	Disease transmission (e.g. digital dermatitis)	X												X	X	X									X										5
				Pain, trauma, discomfort																					X	X		X								X	4
8	**HOUSING**	**Lack of space for exercising**	NO	Locomotion disorders	X					X							X	X	X																			4
				Immunosuppression, less oestrus expression, reduced fertility, ketosis	X															X	X	X	X	X	X	X											8

				Locomotion problems, behaviour disruption, social stress, too little rest	X					X							X	X													X		X	6
9	**HOUSING**	**Poor maintenance of flooring**	NO	Leg injuries, claw disorders, pain	X					X							X	X	X															5
10	**HOUSING**	**Poor stall (cubicle) design**	NO	SARA, ketosis, reduced fertility	X																		X											2
				Leg injuries, claw disorders, pain	X					X							X	X	X															5
				Systemic mastitis and trauma, including teat problems	X														X						X	X		X						5
				Too little rest, behaviour disruption and prevention, pain, fear						X	X	X																					X	4
11	**HOUSING**	**Use of cow trainers**	NO	Stress, fear, pain, disrupted behaviour																													X	1
12	**HOUSING**	**Walking tracks too long, or poorly maintained**	NO	Ketosis, reduced fertility, reduced oestrus expression	X																		X											2
13	**HOUSING**	**Inadequate feeding installation**	NO	Behaviour disruption and prevention, pain																													X	1
14	**HOUSING**	**Inadequate floor (limited to passage ways, feeding and milking areas)**	NO	Fear of slipping and falling, inhibited maintenance and social behaviour, pain																													X	1
15	**HOUSING**	**Inadequate or lack of handling/ restraining facilities**	NO	Behaviour disruption and prevention, pain, fear																													X	1
16	**HOUSING**	**Poor calving conditions**	NO	Systemic mastitis and trauma	X														X						X	X		X						5
17	**MANAGEMENT**	**Mixing animals from different groups**	NO	Social disruption, pain, fear																											X		X	2
18	**MANAGEMENT**	**Withholding necessary veterinary therapeutic health care/poor health care and welfare plan**	NO	Locomotion problems, pain	X					X							X	X								X								5

19	**MANAGEMENT**	**Improper operational pain management**	NO	Reduced DMI, metabolic disease, reduced fertility	X																		X			X		X	X	X				6
20	**MANAGEMENT**	**Inadequate antimicrobial treatments**	NO	Increased duration or severity leading to chronic mastitis	X																				X									2
21	**MANAGEMENT**	**Inadequate biosecurity**	NO	Uterus infection, reproductive failure, abortion, metabolic stress due to disease	X																		X	X		X		X							5
				Behaviour disruption																															0
22	**MANAGEMENT**	**Inadequate clinical health monitoring**	NO	Claw disorders, infectious foot disorders, pain	X					X							X	X																	4
23	**MANAGEMENT**	**Inadequate preventive medicine, herd-health management: infectious disease**	NO	Infectious foot disorders, pain	X					X							X	X																	4
24	**MANAGEMENT**	**Insufficient or inappropriate care of animals by stockperson**	NO	Foot injuries, infectious foot disorders, pain	X					X							X	X																	4
				Increased duration or severity of mastitis	X																				X	X		X							4
25	**MANAGEMENT**	**Poor health care and welfare plan**	NO	Claw disorders, infectious foot disorders, pain	X					X							X	X																	4
26	**NUTRITION AND FEEDING**	**Improper ration composition**	NO	Claw disorders, laminitis, pain	X					X							X	X																	4
				Mastitis	X																				X	X									3
				Behaviour disorders, reduced rumination	X																														1
27	**NUTRITION AND FEEDING**	**Improper sensory quality of the water source**	NO	Suppressed drinking, thirst, frustration, thermal discomfort																														X	1
28	**NUTRITION AND FEEDING**	**Inadequate transition feeding**	NO	Claw disorders, laminitis, pain	X					X							X	X																	4
				Ketosis, decreased fertility, SARA, immunosuppresssion	X															X	X	X	X	X	X	X	X		X							10

29	**NUTRITION AND FEEDING**	**Overfeeding**	YES	Ketosis, dystocia, milk fever, downer cow, displaced abomasum, decreased fertility	X																				X				X	X							4
30	**NUTRITION AND FEEDING**	**Poor feed quality (roughage)**	NO	Hunger, exhaustion	X																														X	2
31	**NUTRITION AND FEEDING**	**Underfeeding**	NO	Chronic hunger, exhaustion, social stress	X																						X					X			X	4
				Ketosis, exhaustion, decreased fertility, immunosuppresssion	X															X	X	X	X	X	X	X	X								X	10
	Total				**38**	**0**	**0**	**0**	**0**	**16**	**1**	**3**	**0**	*	**0**	**0**	**17**	**17**	**9**	**4**	**4**	**4**	**4**	**12**	**6**	**12**	**13**	**2**	**11**	**1**	**1**	**4**	**0**	**0**	**15**	

201 * no measures proposed in WQ protocols

202

GLOSSARY

Accuracy: the overall correctness of an animal-based measure in identifying a welfare outcome.

Animal-based measure: a response of an animal or an effect on an animal. It can be taken directly from the animal or indirectly and includes the use of animal records. The measure may, for example, be intended to: (i) assess the degree of impaired functioning associated with injury, disease, and malnutrition; (ii) provide information on animals' needs and affective states such as hunger, pain and fear, often by measuring the strength of animals' preferences, motivations and aversions; or (iii) assess the physiological, behavioural and immunological changes or effects that animals show in response to various challenges.

Classification tree analysis: decision tree learning is a method commonly used in data mining. The goal is to create a rule that predicts the value (class) of a target variable based on several input variables. Input variables are sorted hierarchically and split the data into subgroups that are then split using next level variables. The tree is completed when the subset at a node (one of the input variable) all have the same value of the target variable. Classification trees differ from discriminant analysis in that judgements are reached by considering variables hierarchically rather than simultaneously.

Hazard: a factor with the potential to cause poor welfare.

Factor: any aspect of the environment of the animal in relation to housing and management, animal genetic selection, transport and slaughter, which may have the potential to impair or improve its welfare.

Magnitude: a function of the intensity and duration of a positive or negative consequence on welfare.

Management-based measure: an evaluation of what the animal unit manager or stockperson does and which management processes or tools are used.

Measure: a form of evaluation rather than an intervention intended to deal with a problem.

Measurement: the result of the above evaluation (e.g. size and depth of wound, percentage of lame animals).

Non-animal-based measure: a measure of factors (resources or the management) in the environment of the animal, that may be linked to the likelihood of good or poor welfare.

Quantitative risk assessment: a risk assessment that provides numerical expressions of risk and indication of the attendant uncertainties.

Random forest analysis: a random forest grows many classification trees through a bootstrap process. Each tree is built up with a subset of data randomly chosen as well as a subset of predictors. Each tree gives a classification, and we say the tree "votes" for that class. The forest chooses the classification having the most votes - over all the trees in the forest**.**

Reliability: a general term referring to the ability of the animal-based measure to be applied under various conditions, and by different personnel, while still providing similar results.

Repeatability: the level of agreement between repeated measurements of the animal-based measure on the same "sample" by the same assessor, on different occasions.

Resource-based measure: an evaluation of a feature of the environment in which the animal is kept or to which it is exposed.

Risk assessment: a scientifically based process consisting of the following steps: (i) exposure assessment; (ii) consequence characterisation; and (iii) risk characterisation

Robustness: the extent to which an animal-based measure is affected by changes in variables, such as environment, time of day, etc.

Sensitivity: the minimum level of welfare outcome change that will be detected by the animal-based measure.

Specificity: the extent to which an animal-based measure is specific for one welfare outcome, or relates to several outcomes.

Threshold: a cut-off value when an animal-based measure is considered to be indicative of a defined welfare outcome.

Validity: the fitness of an animal-based measure that has been properly developed, optimised, and standardised for an intended purpose. Validation includes estimates of the analytical and diagnostic performance characteristics of the measure/indicator (i.e. sensitivity and specificity).

Welfare: means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if it is healthy, comfortable, well-nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states, such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling and humane slaughter/killing. Animal welfare refers to the state of the animal, whereas the treatment that an animal receives is covered by other terms, such as animal care, animal husbandry, management, and humane treatment.

Welfare indicator: an observation, a record or a measurement used to obtain information on an animal's welfare. An indicator is not necessarily measured and it may be a trend.

Welfare outcome: a consequence for the welfare of an individual or group of animals of genetic selection or modification or of a period of housing, management, handling, transport, stunning or other treatment.

Welfare outcome indicator: an observation, a record or a measurement used to obtain information on an individual animal’s welfare that can be reliably used in practice by trained people. It may be the outcome of genetic selection or modification or of a period of housing, management, handling, transport, stunning or other treatment.