SCIENTIFIC OPINION

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

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

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BACKGROUND AS PROVIDED BY 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[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 Community level for dairy cows. Two main areas of action of the Community Action Plan on the Protection and Welfare of Animals 2006-20108 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 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

[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

97 negative effects on the welfare of dairy cows and to what extent these negative effects can be or not
98 prevented through management.

99

ASSESSMENT

1. Introduction

There are no specific rules laid down at the European Union level for the welfare dairy cows, although the intention, outlined in the Community Action Plan on the Protection and Welfare of Animals, is to introduce 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 and is divided into three main sections. Since this is the first of a series of related opinions, 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 (the main part of the opinion) discusses the four terms of reference outlined in the mandate. A short 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 and lead to good welfare of dairy cows from pathological, technical, physiological and behavioural points of view. The resulting scientific opinion consists of a scientific report, an overall scientific opinion (EFSA, 2009a) and four risk assessments dealing with four broad categories of welfare outcomes; (i) metabolic and reproductive disorders (EFSA, 2009b), (ii) udder disorders (EFSA, 2009c), (iii) leg and locomotion problems (EFSA, 2009d) and (iv) behavioural disorders, fear and pain (EFSA, 2009e). In the risk assessments, factors that are risks for poor cattle welfare (hazards) were identified and the risks were assessed separately for tie-stalls, cubicle houses, straw-yards and pasture. One recommendation from this opinion 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 lead was followed by the World Organization of Animal Health (OIE), whose statement on welfare referred to: (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. While the term

"animal welfare" refers to the state of an individual animal, in practical circumstances welfare is often measured at the group or herd level. The EFSA opinion was based on a multidimensional concept of welfare that included both 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 focussed primarily on animal-based indicators that could be monitored and used during inspection to assess current levels of welfare (Keeling, 2009). Welfare Quality proposed four welfare principles, good feeding, good housing, good health, and appropriate behaviour, that were linked to 12 criteria that result in good welfare (Blokhuis et al, 2010). The four principles have some similarity in objective to the Five Freedoms (FAWC, 2009) and the OIE description of animal welfare (OIE, 2011) and so can be considered as useful guideline for achieving good welfare (Rushen et al. 2011). The 12 Welfare Quality criteria include: absence of 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 measures of welfare, such as those of body condition, lameness, avoidance distance and presence of tethering or access to pasture (Welfare Quality, 2009; Forkman and Keeling, 2009).

The measures of welfare have links to the four broad categories of welfare outcomes for dairy cows considered in the EFSA opinion. Thus, in general, the concepts of animal welfare used by the Welfare Quality project and the EFSA scientific 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 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 dairy cow welfare opinion, and in this current opinion we use the new terminology according to the Guidance on Risk Assessment for Animal Welfare (EFSA, 2011).

In the previous EFSA scientific opinion on the welfare of dairy cows (EFSA, 2009a) the word 'hazard' is used to mean something that increases the risk of impaired welfare. The word 'hazard' 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 we are 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 this opinion.

1.2. Concepts

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, bedding material etc., 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 the 'factors' acting upon the animal and both factors and consequences (sometimes also called adverse effects) can be characterized using appropriate resource, management and animal-based measures.

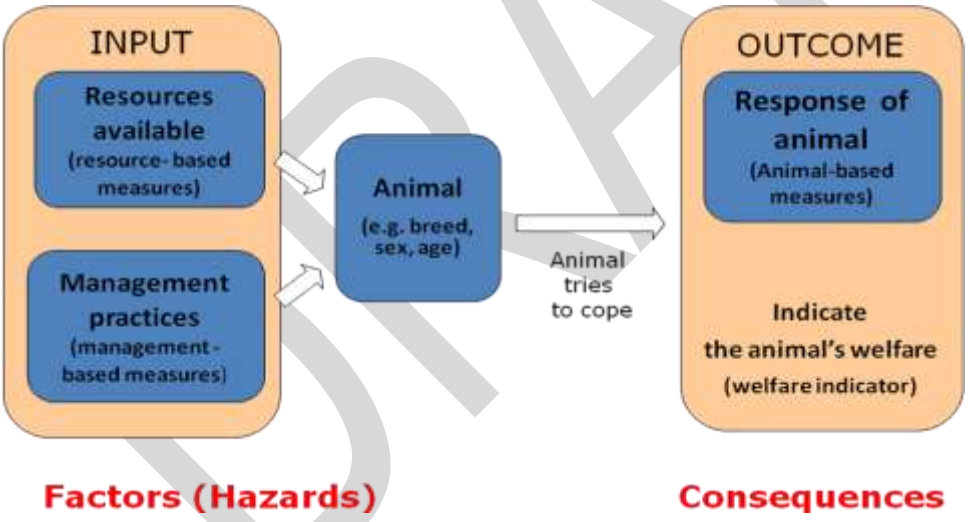

Figure 1. An overview of the terminology

In most cases the responses of the animal are adaptive, with little impact on its welfare, which indicates that the animal can cope rather easily with the factors to which it is exposed. But sometimes the response is of such a magnitude that it indicates that the animal has had difficulty in coping or was not able to cope with these factors and consequently the animal's welfare was impaired. For example, the animal may become injured, diseased or die. Sometimes a major response can be the outcome of many days, weeks or months of more minor responses, 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 that welfare has been affected (see glossary for definitions of animal-based measures and welfare outcome indicators). There is a continuum between these major responses, which indicate a clear increase or decrease in welfare, and the 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 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 as to 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 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 meat inspection, disease reporting systems (surveillance), milk production records and so on.

1.3. Essential attributes of animal-based measures.

Animal-based measures of welfare in principle are similar to diagnostic tests of disease, and the same quality criteria, assessment protocols and terms (see glossary) should be applied. 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 (outcome classification) approaches in general 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, economical etc.). In the context of diagnostic tests for animal diseases, specific validation protocols have been established to estimate 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.

Welfare, like health, 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.

In the absence of systematically collected scientific study and field data that allow quantification of the association between the tests (animal-based measures) and welfare, the diagnostic quality of individual or combined animal-based measures to identify important welfare outcomes relies on expert opinion.

2. How we address 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 EFSA scientific opinion on the welfare of dairy cows. These factors were ranked according to the risk estimate scores allocated to them by the experts in the dairy cow working groups and linked to the lists of animal-based measures identified when addressing the 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 fully explore the diagnostic quality (i.e. their validity, reliability and feasibility) of selected animal-based measures towards specific welfare outcomes – similar to what is done in the validation of diagnostic test assays.

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. We tried to group these

'gaps' to identify any common features. In this way we could address TOR 3 in the mandate which asks whether there are animal welfare issues that can not be assessed using animal-based measures and what kind of alternative solutions are available to improve the situation.

TOR 4 asks 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 (2009) affecting dairy cattle welfare), 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 critically review 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 two different previous approaches and put them into a single operational approach.

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)

The fact that a recommendation from the EFSA scientific opinion 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 the *risk* of cows lying down outside of the cubicles, the most appropriate way to assess whether or not the intended welfare improvement is actually achieved would be by observing where the cows choose to lie down. 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) since it clearly specifies the animal-based measure (tramped teats) to be recorded to determine whether or not the recommendation is fulfilled. Still 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.

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

Thirdly, for somer factors affecting welfare, the animal-based measure is clearly the 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 we must assume that the expected welfare outcome of all of these recommendations is being achieved. However, if a high prevalence of lameness were found on a farm, then we should 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 conclusion, 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. When answering this TOR the focus is on the use of animal-based measures.

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 in a particular measure should be set, but have focussed instead 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 (section 1.3).

Each of the 105 recommendations considered to be of importance in the EFSA scientific opinion on the welfare of dairy cows (2009) was considered in turn to determine measures (animal-based and non-animal-based, see glossary) that would be appropriate to evaluate whether or not the recommendation is being fulfilled on the farm (Appendix 1). This was initially carried out by a smaller group of experts and then discussed and agreed upon in plenary 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. Note, this allocation of potential animal-based and non-animal-based measures was done for all EFSA recommendations, irrespective of how the recommendation was formulated (section 2.1). In some cases, the appropriate welfare indicators are sufficiently described by Welfare Quality (Welfare Quality, 2009). In most cases where the source is elsewhere, this source is referenced in the scientific opinion on the welfare of dairy cows (EFSA, 2009a) or in the book "The welfare of Cattle' (Rushen et al, 2008) so text and references are not replicated here. However, the group did not conduct a detailed literature review to examine what information (if any) was available on the validity, reliability and feasibility of these measures (see section 1.3), and so the appendix can be considered the result of expert opinion.

Efforts have been made to propose measures that can be recorded by a veterinary or other inspector on-farm. 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 table with the 105 recommendations in Appendix 1 was sub-divided into several smaller tables reflecting the topics of the different sections 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, 2009b, 2009c, 2009d, 2009e). Each table (Table 1- Table 7) presents the recommendations related to the topic, the potential animal-based and non-animal based measures. 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 welfare indicators 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 measurement should be selected to address the specific objective (i.e. the recommendation).

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). However it is not our intention, nor is it possible within these tables to describe how the individual observations and measurements should be made or how they should be interpreted in the assessment of welfare outcomes since that 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 link broad categories such as fertility to individual scientific communications. For this reason, Appendix 2 presents a comprehensive list of all animal-based measures referred to in Appendix 1 and so in this report. This 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 the comprehensive review publications (EFSA, 2009a; Welfare Quality, 2009; Rushen et al. 2008). Original communications will only be quoted when they provide a self-sufficient account of methodology and interpretation.

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 (2009), together with a list of potential animal and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The complete text is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See glossary for definitions of the terms animal-based and non-animal-based.

Recommendations (EFSA, 2009a)	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)	Body condition Metabolic profile (e.g. βOHB) Rumenal impaction Faeces consistency Milk composition. (e.g. fat/protein) Fertility records Laminitis	Diet composition Feeding strategy
Feeding systems should allow every cow to meet her 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)	Body condition Metabolic profile (e.g. βOHB) Rumenal impaction Faeces consistency Milk composition. (e.g. fat/protein) Fertility records Feed intake Behaviour at feeding time	Inspection of feeders 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)	Body condition Metabolic profile Feed intake Incidence of milk fever Incidence of ketosis	Diet composition
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,)	Waiting and agonistic behaviours at water points Observation that cows do put their mouths into the water	Inspection 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. body condition, 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 like 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 opinion on the welfare of dairy cows (2009), together with a list of potential animal and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The complete text is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See glossary for definitions of the terms animal-based and non-animal-based.

Recommendations (EFSA, 2009a)	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).	Cows lying in passage Agonistic behaviours (e.g. chasing-up from cubicles) Time spent lying down 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) Teats 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	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 with high up on legs and on back	
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
Gas concentrations in dairy cow houses should not exceed 10ppm ammonia, 0.5ppm H_2S (37)	Animals coughing Watery eyes Respiratory distress and collapse	
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. Lameness	Floor surface, dimensions of walking area, depth of slurry
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)	Lameness	
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.	

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, high prevalence of locomotor disorders, lesions of skin, knees, hocks and feet) and inspection of records (e.g. mastitis, lameness). Non-animal based measures include inspection of facilities (e.g. measurements of cubicle dimensions, inspection of bedding, facilities for foot care) and inspection of records (e.g. routine foot trimming and foot hygiene). Appropriate selection of a sufficiently diverse range of measures, can determine the impact of resource and management factors on specific welfare outcomes (e.g. mastitis, lameness, injury, thermal discomfort).

401 **Table 3. Abbreviated list of recommendations related to MANAGEMENT, INCLUDING MANAGEMENT AT**
402 **CALVING as presented in the scientific opinion on the welfare of dairy cows (2009), together with a list of potential**
403 **animal and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The complete text**
404 **is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See glossary**
405 **for definitions of the terms animal-based and non-animal-based.**

Recommendations (EFSA, 2009a)	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 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
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	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	Presence of sick-pens Procedure for handling of downer cows Presence of decision rules 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 or 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.

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 stock.	Record of procedures for 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 opinion on the welfare of dairy cows (2009), together with a list of potential animal and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The complete text is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See glossary for definitions of the terms animal-based and non-animal-based.

Recommendations EFSA, 2009a)	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 round on way to milking area, kicking off clusters. Evidence of contagious mastitis, teat injuries.	Records of milking machine maintenance
Cleaning of udders should take full account of the risk of transmission of pathogens.(58)	Cleanliness of udder. Evidence of contagious 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 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 contagious 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).	Evidence of acute environmental systemic (E. coli) mastitis: fever and general malaise and teat and udder hypersensitivity. Evidence of contagious mastitis: Clots and blood in milk, udder and teat inflammation and ulcers, somatic cell counts	Record of programme for prevention and control of mastitis. 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 injuries, 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 (2009), together with a list of potential animal and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The complete text is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See glossary for definitions of the terms animal-based and non-animal-based.

Recommendations	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)	Lameness Overgrown and misshapen hooves	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 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)	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).	Cows with sole ulcers have hoof blocks	Facilities for hospitalisation of severely lame cows Evidence of knowledge of how to carry out pain management procedures. Records of provision for pain relief (eg 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 and pain relief programme and facilities for preventive treatments (e.g. hospital facilities, presence of foot bath).

Table 6. Abbreviated list of recommendations related to DISEASE CONTROL as presented in the EFSA opinion on the welfare of dairy cows (2009), together with a list of potential animal and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The complete text is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See glossary for definitions of the terms animal-based and non-animal-based.

Recommendations	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)	Infectious diseases (e.g. clinical signs) Presence of guaranteed infectious disease free health certificate	Records of health and biosecurity programmes and of cattle movement.
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 recording system for biosecurity programmes. Presence of a quarantine. Evidence of requirements for the introduction of new heifers and bulls e.g. disease free status 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	Evidence of infectious diseases.	Records of animal movements of quarantine and of management of newly introduced animals

poor welfare and spread of infectious diseases (94)		
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

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 clinical signs associated with the disease are not listed in the table.

Table 7. Abbreviated list of recommendations related to GENETICS AND BREEDING as presented in the EFSA opinion on the welfare of dairy cows (2009), together with a list of potential animal and non-animal-based measures to indicate whether or not the recommendation is fulfilled. The complete text is provided in Appendix 1 and only the number of the recommendation(s) referred to is presented here. See glossary for definitions of the terms animal-based and non-animal-based.

Recommendations	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, 4 ,)	Measures of life expectancy (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 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	

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 (2009) scientific opinion 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 the 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, 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). But it is also desirable to identify animals whose welfare is decreasing or increasing as early as possible, 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 done. For example, a high milk somatic cell count indicates an immune response to 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 (2009). But 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 other ante-mortem and post-mortem slaughterhouse measures that give 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. They can be expected to be more important, however, in subsequent opinions on animal-based measures and welfare-outcome indicators.

2.1.2. Indicator selection

We have concluded that the indicators necessary to investigate and check the fulfilment of the recommendations in the EFSA scientific opinion (2009) should consider both input factors (resource and management-based indicators) and consequences (animal-based indicators). These indicators (see Appendix 1 for a full list) may be categorised as follows.

- Animal-based indicators:
  - *Direct* indicators (observations and measures from the animals made during the welfare assessment on farm, ante or post mortem (e.g. behaviour, clinical signs of injury, lameness)
  - *Veterinary procedures* measurements that can be obtained only by a veterinarian or other authorised individual (e.g. from blood sample)
  - *Records* of animal breeding, milk yield and milk quality, fertility, health etc. These 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 indicators (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 program).

The selection of animal- and non-animal based indicators is governed by the areas of concern (nutrition and feeding, housing, genetics and management) as present in the EFSA Scientific opinion (2009). The monitoring of problems relating to nutrition and feeding requires observations of body condition, 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 observations (e.g. ease of movement, 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. Selection, transposition and use of indicators

It would be quite unrealistic to recruit all of the indicators 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 indicators necessary to address the specific objectives of a specific assessment. 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 a 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. An assessment of the impact of nutrition and feeding practices on the productivity and welfare, including health, of dairy cows would select from the toolbox a very different set of indicators. An assessment made for legislative purposes, especially when intended for presentation as evidence in support of a ban on a particular management practice or a failure of resource, would need to provide forensic evidence, including that from veterinary procedures, which may not normally be obtained from a routine welfare inspection.

The animal-based measures highlighted in this opinion are deliberately general in their nature and in practice they would be developed according to SOPs (standard operating procedures) leading to more detail about how to carry them out. However, the first stage in a programme of welfare assessment, whether for the purposes of quality control, or as the foundation for implementation of a welfare or disease management policy, employs a broad spectrum of animal-based measures to highlight the most important problems, for that particular farm. Subsequent assessments could then concentrate on more detailed inspections by which to measure change.

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 (buildings) and genetic selection may take many years (see Section 2.4). 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 to 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 are needed to provide a baseline for comparison.

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[5]) 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 shall be proportionate to the risk. Again the precise details of any risk assessment will need to be determined.

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

- By a farmer to inform management decisions
- By a farmer to track changes in welfare as a result of changes in management or environment
- By an animal scientist or veterinary 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 a part of a quality assurance or labelling scheme
- By the competent/responsible authority to check that a farm satisfies minimum 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.

2.2. 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

[5] 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

Quality project covers the main hazards (referred to as input factors in figure 1) identified in the EFSA scientific opinion 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 hazards characterisations were identified for each of the four EFSA risk assessment reports (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 (2009).

Table 8. Number of selected (for detailed consideration) and of all hazards (in parentheses) by the respective category combinations as originally proposed in the (2009) scientific opinion. They are grouped horizontally according to which scientific opinion and to which housing system they refer, and vertically according to the four hazards categories used in the scientific opinion. For each combination of housing system and hazard category, the top-ranking (based on the risk estimate value) hazards 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	MANAGE-MENT	NUTRITION & 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 & 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 main hazards from the EFSA (2009) scientific opinion were then placed in a table with rows showing the main different 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 EFSA scientific opinion and vice-versa. The decisions, about when a Welfare Quality measure addressed a specific hazard characterised in the EFSA scientific opinion 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.

2.2.2. Main findings and issues

First, the only measures in the Welfare Quality protocol that were not linked to a main hazard identified in the EFSA opinion were those related to adequacy of water supply. However, an inadequate supply of water was considered a hazard 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 we defined these here.

Thus, we conclude that the EFSA opinions did not overlook any main hazards that were identified during the development of the Welfare Quality Protocol.

There were 3 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. 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. Assessing constraints and disruption of behaviour would require extensive and time consuming behavioural observations to detect. This may be a reason 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

In some cases, adverse effects of the hazards were covered by more than one Welfare Quality measure (max -10 measures). The two adverse effects for which there were 10 potential Welfare Quality measures related to the hazards 'inadequate transition feeding' and 'underfeeding', and more specifically to the adverse effects '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.

On the other hand there were several Welfare Quality measures that were related to the adverse effects of several hazards (max – 17 adverse effects). This may suggest that just 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. Lameness was the measure implicated in the highest number of hazards. Lameness is a major welfare problem itself but it also gives information about the general situation on a farm. This is probably one of the reasons why so much attention has been paid to developing reliable measures of lameness in dairy cattle.

In summary, the degree of overlap between the main hazards identified in the EFSA scientific opinion 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 a measure in its protocol, whenever possible an animal-based measure. This measure is very clearly linked to the Welfare Quality 12 criteria (see section 1.1), but it is not always so clearly linked to a specific adverse effect presented in the EFSA opinion. On the

other hand, the EFSA scientific opinion is very transparent in identifying hazards and their adverse effects, but does not give comprehensive information about which welfare outcome indicators 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 (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 opinion, even if they are not identical. For example, in the EFSA opinion 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 and welfare outcome. An animal can be immunosuppressed but not sick and it can be sick without necessarily being immunosuppressed beforehand.

One unresolved issue is the following. Often, a particular hazard will lead to several adverse effects. For example, the EFSA scientific opinion identified the hazard, 'absence of bedding material', which can lead to several different consequences, such as systematic mastitis, leg injuries and claw lesions etc. The Welfare Quality project only uses the animal-based measure 'damage to the integument including bare patches and injuries'. However, we do not fully know if the presence of damage to the integument due to lack of bedding as identified in the Welfare Quality protocol, would also indicate that there was a higher occurrence of mastitis.

The discrepancies between the EFSA scientific opinion 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 they did not require a trained veterinarian or ethologist to be able to record them. The aim was that any person with a good animal knowledge could perform them reliably after training. The adverse effects in the EFSA scientific opinion are often expressed in terms of a veterinary diagnosis or experimental studies. On the other hand, if the cow is sick with disorders specified in the EFSA scientific opinion, 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.

The Welfare Quality protocol was designed to be carried out on farm within one day, which meant

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, but it was considered as reliable 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 opinion, but it is not specified how these states could be assessed. These terms are grouped in Welfare Quality as indicators of the emotional state of the animal and are assessed using 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.

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 TOR3, the tables developed for TOR1 (how animal-based measures can be used to fulfil recommendations) and TOR2 (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 the available outcome measures did not adequately link welfare to the hazard causing it.

From the table of recommendations presented in Appendix 1, a number of 'gaps' were found. However, it became apparent that there are similarities between some of the 'gaps' (or some of the welfare issues to which they apply) as to why animal-based measures are not currently being used, or why they can only be used with difficulty to assess that particular 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.

719 ### 2.3.2. Welfare issues for which alternative and more feasible non-animal-based
720 ### measures are already available

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

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

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

739 A second common reason is that the same poor outcome may be the result of many different hazards,
740 and so the precise reason for the poor outcome cannot be determined. For example, recommendations
741 20 to 31, 32, and 40 to 45 refer to problems related to housing design, mostly inadequate cubicle or
742 tie-stall design, and lack of sufficient space. Animal-based measures are available to detect the result
743 of these hazards, such as the ability to move freely, abnormal posture, injuries or skin lesions on knees
744 or hocks, lying in the passageway. However, these outcomes can also result from other hazards and so
745 it would be very difficult to connect these measures directly to a specific hazard. Again, the solution
746 would be to simply examine the adequacy of the cubicle design, as well as the number of cubicles, or
747 the presence of narrow passageways. Such measures of 'engineering standards' are important when
748 designing facilities and getting it right at that time can prevent later welfare problems. The situation is
749 similar for the recommendations concerning number and inspection of water points (11-15),
750 measurement of noxious gases like ammonia, CO_2, H_2S (37,38), light levels (39), temperature
751 measurements (33, 34, 35), and ventilation rates (33), as well as recommendations 52, 103 and 53,
752 which deal with welfare issues associated with the use of cow trainers, electric goads and with stray
753 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, though 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 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 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.

The consequences of past selection are still present in the population today so if there is an incidence of 30% clinical mastitis, it can be inferred that 20% to 22% would represent the environmental component and 8% to 10% the consequence of past selection. With 5% genetic variability with respect to clinical mastitis, the extreme genotypes in a farm will have 20% and 40% incidence rates and most of the clinical cases that can be attributed to genetics (past selection with emphasis on increased yield) will occur in those cows producing at above the population average.

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 (Osteras et al, 2007, Philipsson and Lindhe 2003). 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 fertility, ease of calving, conformation, somatic cell counts, incidence of mastitis and lameness, 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 the 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 "Feeding systems should allow every individual cow to meet her needs for quantity and quality of feed". We propose that observation of behavior at feeding time as a measure and in the Welfare Quality dairy cattle protocol (Welfare Quality, 2009) agonistic interactions 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 characterized by 'increased constraint on time available for activities' and 'behavioural disruption'. Both would require behaviour observations over several days or a weeks to be addressed.

Fortunately, technology is becoming available that allows automatic monitoring of some behaviours, and some is 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 Passille 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 welfare indicators are already available and, if implemented, can support a welfare assessment programme.

2.3.5. Specialized 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.

Whoever is involved in any animal-based assessment, it is important that they are appropriately educated so that they fully understand their responsibilities and role and the importance of doing it properly, 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. As stated above, of particular importance here is education, so that the person knows the importance of taking the animal-based measure; the development of technical skills, so that the person knows how to take the measure in the correct way; and competence, that is to say the ability to actually do it. 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 critically assess the available literature 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 opinion (2009) 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 to subsequently discuss and interpret the given scores. In addition to deriving the results of the analysis and the conclusions and recommendations from it, we also spend some time 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 & 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 the various 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 are considered to be the main factors in the various husbandry systems which have been scientifically proved 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 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, median as well as min and max (range of) scores for each hazard. Since it was quickly identified 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: 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 person (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 and exclude long term management plans), and (c) without consideration of potential financial constraints, i.e. assuming that the manager could always take the decision to change if they wanted. It was not our intention to imply that changes like genetic improvement and constructing new building are *not* manageable, so the implications of focussing 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 the hazard itself. At first glance, there appears to be substantial repetition of hazards in the table. However, they relate 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 the 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 to help clarify several apparent disagreements between experts.

For some experts the probability or likelihood that a change in management would actually be implemented was also to 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 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 Generalized Linear Model (GLM) approach with the three main effects and all 2-way interactions.

2.4.4. Results of 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 a 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. The slight drop in average management score is attributed to the modification of the definition of what can be achieved through management in 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 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 a 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 10^{th} and 90^{th} percentile values for RE and Mag in order to identify those hazards most relevant for further exploration and discussion (Figure 2).

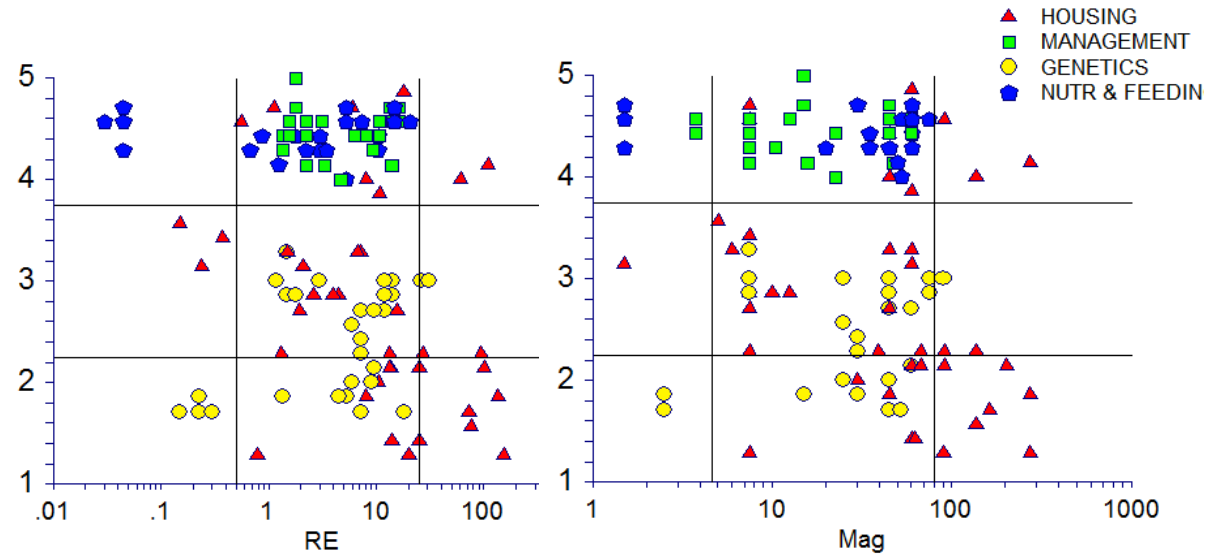

Figure 2– Average management scores (8 experts, y-axis) of all selected hazards by risk estimate RE, left) and by magnitude of effect (Mag, right), coded by Hazard Category (Housing, Management, Genetics, Nutrition & Feeding). Horizontal lines indicate average management scores below 2.25 (poor) and 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 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 for some hazards.

2.4.6. Discussion

It is obvious that routine management, nutrition and feeding-related hazards have higher management potential, whereas the genetic composition of the herd and structural aspects of the building design have 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 quicker and easier, assuming the stockperson is willing and able to make the change, than for the latter set of hazards, that 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 that also the quality of the bedding is 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. But 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. But, 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. And probably these are best managed 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 new technique testing of housing systems to minimise that a system is constructed that is inherently poor from an animal welfare point of view. This seems to be an important aspect 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 animal 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 therefore 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, the time available to collect it as well as financial constraints.

Several times in this report, the possibility of a 'toolbox' of validated, reliable welfare outcome indicators 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 take different tools. There are, however, certain basic similarities in how this system would work and 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 animal-based measures or combination of welfare indicators 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 animal-based measure(s) to verify whether the action has resulted in the intended effect. In many respects this is similar to what is 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 e.g. a lame cow may be less competitive at the food trough, so not have the most appropriate diet 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 neither links between hazards (e.g. flooring, hygiene in the stalls) nor links between consequences (e.g. pain leading to lameness, metabolic disorders), nor links between animal-based measures (gait scoring and somatic cell count) are singular. They also do not need to be of the same strength. That is to say of the similar specificity. In several cases, some of which are discussed earlier in this report, different hazards might lead to the same welfare outcome, i.e. to the same consequence. In other cases, which are also discussed earlier in this report, the same hazard may lead to several different welfare outcomes. Furthermore, while in some cases, one welfare

outcome can be measured in a valid, accurate and robust way by one animal-based measure, sometimes combination of animal-based measures may be needed. Alternatively, as also discussed previously, an 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 generally 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 indicators might be chosen from the toolbox for a certain monitoring goal. But as the work in this scientific opinion has shown, it is no easy task to combine information from different sources, originally collected for 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 optimize the toolbox in a direction that we would know which combination of indicators is best suited and most efficient in measuring presence of welfare outcomes and hazards of interest. To achieve this, one needs to identify and fully explore 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 centralized database, from which to explore interactions between hazards, welfare outcomes and indicators using specific statistical tools (Sanisys, 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. Whereas an advantage of the database approach is the improved transparency and consistency of results based on "objective data" and the increasing possibility to move towards quantitative risk assessment in animal welfare.

In order to further explore a possible route of how to proceed towards quantitative risk assessment of animal welfare, a report was commissioned to a consulting company (Sanisys SA; www.sanisys.net). The resulting 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.

It is further reported that data collection can be from one or several sources e.g. ongoing recordings (field records and monitoring), other databases, designated research projects, risk assessments and

expert opinion. From these relational databases, automated data analysis routines can be used to facilitate communication between the different courses 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. But the data analysis can also contribute to identifying the links and the strengths of the links between input factors and welfare consequences that are currently lacking 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.

A final point in this discussion on the development of tools to monitor animal welfare deals not only with what is recorded and how it is analysed to generate new knowledge that can be used in risk assessment, but also with the implications of the results gathered on farm. Some aspects of this have already been mentioned earlier in this opinion. Benchmarking of animal-based measures on a large scale might also be particularly important for early detection of welfare changes that would not otherwise be detected, or would not have been detected until much later. This would allow the earlier 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. On the positive side, 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 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 current EFSA mandate on meat inspection.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

RECOMMENDATIONS

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A. APPENDIX 1

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

	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 life expectancy (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 farm or national level from measures made on single visits to individual farms* WQ: 6.1.3.1 (Absence of injuries: lameness 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 life expectancy (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) 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.	Body condition 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 sire and dam selection in order to avoid inbreeding.
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 GM report of AHAW) 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	Body condition Metabolic profile (e.g. βOHB) Rumenal impaction Faeces consistency Milk composition. (e.g. fat/protein) Fertility records Laminitis 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.	Body condition Metabolic profile (e.g. βOHB) Rumenal impaction Faeces consistency Milk composition. (e.g. fat/protein) Fertility records Feed intake Behaviour at feeding time WQ: 6.1.1.1 (Absence of prolonged hunger: body condition score) 6.1.4.1 (Expression of social behaviours: agonistic behaviour)	Inspection of feeders 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	Observation that cows do put their mouths into the water	WQ:Inspection of water points. 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	Waiting and agonistic behaviours at water points WQ:6.1.4.1 (Expression of social behaviours: agonistic behaviour)	WQ:Inspection of water points. 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 sings of intoxication.	Analysis of water source WQ: Inspection of water points. 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	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 spiting, - rumen bolus in and around feed troughs Toxic substance and metabolites in milk body tissue, clinical sings 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 feed-stuffs 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 spiting, - rumen bolus in and around feed troughs Toxic substance and metabolites in milk body tissue, clinical sings 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	Body condition Metabolic profile (e.g. βOHB) Rumenal impaction Faeces consistency Milk composition. (e.g. fat/protein) Fertility records Feed intake Behaviour at feeding time WQ: 6.1.1.1 (Absence of prolonged hunger: body condition score) 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	Body condition Metabolic profile Rumenal impaction Faeces consistency 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
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 Cows lying in passage. Injuries such as hair loss, skin damage, swollen knees or hocks. 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
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) Teats 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) 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,) 6.1.3.1 (Absence of injuries: lameness	Cubicle dimensions and design
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) Teats 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) 6.1.3.1 (Absence of injuries: lameness 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	Cows lying in passage Agonistic behaviours (e.g. chasing-up from cubicles) 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) 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) Teats 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) Teats 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,) 6.1.3.1 (Absence of injuries: lameness 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) Teats 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) 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) 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	Body condition Metabolic profile (e.g. βOHB) Rumenal impaction Faeces consistency Milk composition. (e.g. fat/protein) Fertility records Feed intake 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: 6.1.4.1 (Expression of social behaviours: agonistic behaviour)	
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 width.	Difficulties in moving around building (e.g reluctance to move). Slipping. Aggression behaviour, WQ: 6.1.4.1 (Expression of social behaviours: agonistic behaviour)	

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. Aggression behaviour., Cows can all feed at the same time when food is not *ad libitum.* Injuries such as hair loss, skin damage, swollen knees or hocks WQ: 6.1.2.1 & 6.1.2.2 may be designed) 6.1.2.1 (Comfort around resting: animals colliding with housing equipment during lying down) 6.1.3.1 (Absence of injuries: integument alterations) 6.1.4.1 (Expression of social behaviours: agonistic interactions)	
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) 6.1.3.1 (Absence of injuries: integument alterations)	
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,
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 e.g. huddling (individuals in close proximity to one another in order to reduce heat loss), shivering. Attempts to seek shelter. Posture	Presents 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.	

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: ammonia 10 ppm, H_2S a measurable amount e.g. 0.5 ppm, carbon dioxide 3000 ppm. **H**	Animals coughing Watery eyes Respiratory distress and collapse 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 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.	Cows standing when majority of herd are lying. Cows lying in dunging area. Difficulty in lying or standing 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) 6.1.4.1 (Expression of social behaviours: agonistic behaviour)	

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) Teats 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 with high up on legs and on back WQ: 6.1.2.1 (Comfort around resting: cleanliness) 6.1.3.1 (Absence of injuries: integument alterations)	Presence of sufficient bedding
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. 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. Lameness WQ: 6.1.3.1 (Absence of injuries: lameness)	
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 indicator of depression. Individual animals which do not show normal behaviours such grooming, social interaction and exercise.	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 indicator of depression. Difficulties in changing position – (standing up and lying down behaviour) due skeletal and joint disorders. Inadequate grooming behaviour including excessive grooming of front of 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	tethered animals 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**	Lameness WQ: 6.1.3.1 (Absence of injuries: lameness 6.1.3.2 (Absence of disease: vulvar discharge, milk somatic cell count, mortality, downer cows) 6.1.3.2 (Absence of disease: coughing, nasal discharge, ocular discharge, hampered respiration)	Access to pasture or other outdoor area WQ: 6.1.2.3 (Ease of movement: access to outdoor loafing area or pasture) 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**	Injuries of foot, claw and skin. Leg injuries and disorders associated with slipping. Animals standing in water/slurry WQ: 6.1.3.1 (Absence of injuries: lameness	

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.	Time to enter milking area. Stopping and turning around behaviour. Kicking off clusters. Evidence of contagious mastitis, teat injuries. Avoidance of humans Residual milk WQ: 6.1.3.2 (Absence of disease: milk somatic cell count, teat injuries) 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 to 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 contagious mastitis, teat injuries. Avoidance of humans Residual milk WQ: 6.1.3.2 (Absence of disease: milk somatic cell count, teat injuries) 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 contagious mastitis, teat injuries. Avoidance of humans Residual milk WQ: 6.1.3.2 (Absence of disease: milk somatic cell count, teat injuries) 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.	Increased time to enter milking area. Stopping and turning around behaviour. Kicking off clusters. Signs of contagious mastitis. Teat injuries. Avoidance of humans Residual milk WQ: 6.1.3.2 (Absence of disease: milk somatic cell count, teat injuries) 6.1.4.3 (Good human-animal relationship: avoidance distance)	
58.	Cleaning of udders should take full account of the risk of transmission of pathogens. **H**	Cleanliness of udder. Evidence of contagious 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 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.	Body condition Metabolic profile (e.g. βOHB) Rumenal impaction Faeces consistency Milk composition. (e.g. fat/protein) Fertility records Feed intake Behaviour at feeding time non-milking visits to robot. duration meals WQ: 6.1.1.1 (Absence of prolonged hunger: body condition score, very lean 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, evidence of contagious 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.	Lameness Evidence of discomfort when standing (eg paddling), Foot lesions such as sole ulcer, sole haemorrhage, white line separation. Infectious conditions of claw and skin eg. 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.	Lameness Measure of overgrown and unshaped hooves. Evidence of discomfort when standing (eg paddling), Foot lesions such as sole ulcer, sole haemorrhage, white line separation. Infectious conditions of claw and skin eg. 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 (eg paddling), Foot lesions such as sole ulcer, sole haemorrhage, white line separation. Infectious conditions of claw and skin eg. digital dermatitis. 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**	Lameness Overgrown and misshapen hooves 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 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**	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**	Cows with sole ulcers have hoof blocks	Facilities for hospitalisation of severely lame cows Evidence of knowledge of how to carry out pain management procedures. Records of provision for pain relief (eg use of analgesic, provision of improved bedding
81.	Hoof-trimming should be carried out with care by professionally trained and certified personnel.	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,	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.	Evidence of contagious mastitis. Signs of acute environmental systemic (*E. coli*) mastitis. somatic cell count WQ: 6.1.2.1 (Comfort around resting: cleanliness of udder, flank/upper legs and lower legs) 6.1.3.2 (Absence of disease: milk somatic cell count)	programme for prevention and control of mastitis. Records of diagnostics, , treatments, 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**	Evidence of acute environmental systemic (E. coli) mastitis: fever and general malaise and teat and udder hypersensitivity. Evidence of contagious mastitis: 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. 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)	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 vulval discharge. WQ: 6.1.3.2 (Absence of disease: vulvar discharge)	Records of hygiene procedure eg. Appropriate management f 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**	Evidence of infectious and production related diseases. WQ: 6.1.3.2 (Absence of disease: al measures)	Records of health and biosecurity programmes and of cattle movement.

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: al measures	Evidence of recording system for biosecurity programmes.
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) 6.1.3.2 (Absence of disease: all measures)	Evidence of training, Monitoring system for sings 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) 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 prioritized in order to avoid problems with antimicrobial resistance and associated bad welfare.	Presence 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	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 stock.	Record of 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 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 or 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, eg. 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.
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B. APPENDIX 2

List of animal-based measures from Appendix 1. The measures are described in broad terms (e.g. fertility records, metabolic profiles, feeding behaviour) to indicate the type of observation or measurement that can be used to address specific objectives. 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 indicators will be identified in future. The methodology for recording and interpreting these indicators is based on published scientific evidence and sound clinical practice. The science that underpins most of these indicators is (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 we suggest that readers seeking further details of methodology and interpretation make reference in the first instance to comprehensive review publications (e.g. EFSA, 2009a; Welfare Quality, 2009; Rushen et al. 2008). Original communications are only quoted when they provide a self-sufficient account of methodology and interpretation.

- Body condition as an indicator of how lean or fat the animal is (Welfare Quality, 2009).
- Metabolic profile (e.g. βOHB) milk an blood sampling for e of glucose, urea,albumin, cholesterol, beta-hydroxybutyrate (BHBA) and non-esterified fatty acids (NEFA) as well as some minerals (Na, K, Cl, Ca, Mg, P) as evidence disorders energy and protein metabolism (EFSA, 2009, p68)
- Rumenal impaction
- Faeces consistency - liquid sticky faeces indicate rumenal / gastro interstitial disorders
- Milk composition. (e.g. fat/protein) indicator energy deficiency substantially below normal for breed
- Fertility records
- Laminitis
- Feed intake
- Behaviour at feeding time
- Incidence of milk fever
- Incidence of ketosis
- Evidence of dehydration (e.g. reduced milk yield, urine specific gravity, skin tent test)
- Behavioural evidence that cows are drinking
- Water intake
- Waiting and agonistic behaviours at water points
- Observation that cows do put their mouths into the water

- Cows lying in passage
- Agonistic behaviours (e.g. chasing-up from cubicles)
- Time spent lying down
- Hock, knee and skin lesions and swellings
- Difficulties in changing positions (standing up and lying down behaviour)
- Time spent standing
- Shifting weight from one foot to another
- Posture of cow in cubicle (cows lying with legs extended to another cubicle)
- Teats injuries
- Lying in passage
- Colliding with equipment when standing or lying down
- Getting up with front legs first
- Dog sitting
- Cleanliness of animals with high up on legs and on back.
- Sweating,
- Body temperature
- Animals coughing
- Watery eyes
- Respiratory distress and collapse
- Abnormal walking movement Slipping and falling
- Foot lesions (claw and skin)
- Leg injuries and disorders associated with slipping.
- Skin lesions
- Grooming behaviour in different parts of the body
- Abnormal social interaction and exercise.
- Absence of normal range of resting postures
- Cows interfering with other cows during calving
- Calves not accepted by cows
- Body conditions of calves, neonatal disease and calf mortality
- Dystocia
- Downer cows
- Evidence of wet coat in downer cows
- Aggression to humans,
- Increased reactivity to humans
- Avoidance behaviour to humans
- Evidence of marking methods.
- Infections from ear tagging.

- Occurrence of hot-iron brand on animal.
- Presence of horns in young stock
- Docked tails observable
- Stopping and turning round on way to milking area, kicking off clusters.
- Teat injuries
- Cleanliness of udder.
- non-milking visits to robot.
- Duration of meals
- Reluctance to enter the robot unit.
- Udder injuries
- Evidence of acute environmental systemic (*E. coli*) mastitis: fever and general malaise and teat and udder hypersensitivity.
- Evidence of contagious mastitis: Clots and blood in milk, udder and teat inflammation and ulcers, somatic cell counts
- Behavioural evidence of pain e.g. hypersensitivity to touch on teat or udder, reluctance to move.
- Overgrown and misshapen hooves
- 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.
- Cows with sole ulcers have hoof blocks
- Presence of guaranteed infectious disease free health certificate
- Evidence of infectious diseases
- Measures of life expectancy (e.g. changes in mortality and culling rate, age distribution within herd)

C. APPENDIX 3

Table comparing the 31 measures included in the Welfare Quality dairy cow protocol (as described in section 1.1 of this opinion and in Welfare Quality, 2009) and the 55 main hazards from the EFSA scientific opinion (EFSA, 2009a) obtained as described in sections 2.2.1. An 'X' in the cell indicates that the adverse effect (outcome or consequence as described in Figure 1) arising from that hazard (the hazard characterization) can be covered by that particular measure in the Welfare Quality protocol. There is also a column indicating whether the hazard itself is addressed by the Welfare Quality protocol.

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	Hazard category	Hazard description	Is hazard covered by Welfare Quality protocols?	Hazard characterization	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	God 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	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**	NO	Mastitis	X																					X										2
				Metabolic disorders	X																			X			X		X							4

		traits		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

				Locomotion disorders	X					X							X	X	X													4
8	**HOUSING**	**Lack of space for exercising**	NO	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	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 (1)	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 (3)	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 (3)	X																				X	X									3
				Behaviour disorders, reduced rumination	X																														1
27	**NUTRITION AND FEEDING**	**Improper sensory quality of the water**	NO	Suppressed drinking, thirst, frustration, thermal discomfort																														X	1

		source																																		
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	0	17	17	9	4	4	4	4	12	6	12	13	2	11	1	1	4	0	0	15	

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GLOSSARY

Accuracy (or Validity): The overall correctness of a welfare outcome indicator in identifying a welfare outcome.

Animal-based measure: an indicator of the response of or an effect on an animal. It can be taken directly on the animal or indirectly and includes the use of animal records.

Cascade of welfare indicators: the sequence of animal-based measures / welfare outcome indicators that occurs when an animal is experiencing deteriorating welfare.

Hazard (in this context): a factor with the potential to cause poor welfare.

Factor: any aspect of the environment of the animal, alterations in which may have the potential to improve or impair the welfare of animals.

Fitness (in this context): how well the animal-based measure / welfare outcome indicator reflects the animal welfare outcome and how practical it is to use.

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

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

Predictive welfare indicator: an observation, a record or a measurement that does not indicate a substantial current welfare problem, but identifies an animal whose welfare is changing.

Reliability: a general term referring to the ability of the welfare outcome indicator 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 welfare outcome indicator 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.

Robustness: the extent to which a welfare outcome indicator 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 welfare outcome indicator.

Specificity: the extent to which a welfare outcome indicator is specific for one welfare outcome, or relates several outcomes.

Threshold: a cutoff value when a welfare outcome indicator is considered to be indicative of a defined welfare outcome.

Validity: the fitness of a welfare outcome indicator 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 indicator: an observation, a record or a measurement used to obtain information on an animal's welfare.

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.

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.