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SCIENTIFIC OPINION

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

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

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ABSTRACT

Animal-based measures (ABM) can be used effectively in the on-farm evaluation of broiler welfare in relation to laws, codes of practice, quality assurance schemes, management and also partly for ante-mortem inspection. Some ABM can also be taken post-mortem at the slaughterhouse. Non-animal-based measures can be used when the association between them and the welfare outcome is strong and when they are more efficient than ABM as a means to safeguard welfare. They can also be useful predictors of welfare in broilers. The choice of animal-based measures will depend upon the specific objectives of the assessment. The full list is comparable to a 'toolbox', from which the appropriate set of measures can be selected. The Welfare Quality® protocol provides information on the majority of the welfare outcomes for the main factors identified in the EFSA Scientific Opinions but not those where time limitation prevents it. There is a lack of research on the use of ABM on-farm and in the slaughterhouse to assess pain, frustration, boredom and other negative or positive emotional states in the standard broiler. There are limited management options to prevent poor welfare when the flock is still in the house e.g. to improve the ventilation system. The same applies to negative consequences arising from genetic selection. There is a need for more systematic flock monitoring and surveillance programmes in the broiler industry. Visual inspection has a very high potential to improve animal welfare in broiler production when a range of appropriate ABM is used in the slaughterhouse. Benchmarking can be used to document welfare changes over time, including automatic monitoring and assessment systems. Attention should also be paid to initial and ongoing training of assessors in the field and in the abattoir to ensure valid and robust measurements.

KEY WORDS

Broiler welfare, welfare assessment, risk assessment, welfare outcome indicators, slaughterhouse inspection, on-farm assessment, animal-based measures.

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SUMMARY

This scientific opinion gives an overview of the current and potential future use of animal-based measures to assess the welfare of broilers. The first section presents the background by outlining the findings of previous EFSA scientific opinions in this area, work on broiler welfare carried out within the EU-funded Welfare Quality® project and general issues related to the use of animal-based measures. The second section discusses the four terms of reference outlined in the mandate. The third section addresses ways in which data and information on the links between factors affecting welfare and measures used to assess welfare can best be merged to facilitate further developments in welfare assessment.

Following a request from the European Commission, the Panel on Animal Health and Welfare was asked to deliver a Scientific Opinion on the use of animal-based measures to assess the welfare of broilers. This is in relation to two key areas in the Community Action Plan (2006-2010) on the Welfare of Animals: the first concerns upgrading existing minimum standards for animal protection and welfare, and the second the introduction of standardised animal welfare indicators. The recently adopted EU Strategy for the Protection and Welfare of Animals (2012–2015) also highlights that the possibility of using scientifically validated outcome-based indicators complementing prescriptive requirements in EU legislation will be considered when necessary.

Animal-based measures such as panting, low mobility, high numbers of emaciated birds or high mortality have been used by veterinarians and farmers effectively for many years in the evaluation of the health and welfare of broiler flocks on-farm as well as by scientists to measure the responses of animals as indicators of their welfare. However, assessment in relation to quality assurance schemes and even the new EU broiler directive focuses mainly on measures of the environment (resources) or management (practices), in other words, on risk factors rather than on their consequences for the animal. A European Union (EU) -financed project called Welfare Quality® has been influential in developing a standardised system for the assessment of animal welfare on-farms. In line with the European Commission's intention to adopt a more systematic outcome-based approach to animal welfare, the Welfare Quality® project focused on animal-based measures and produced a welfare-outcome assessment protocol for several species, including broilers. The concepts of animal welfare used in the Welfare Quality® project and EFSA Scientific Opinions overlap considerably, confirming general agreement in the scientific community concerning the definition of animal welfare. The challenge in this Opinion has been to merge the risk assessment approach of the EFSA Scientific Opinions on the welfare of broilers with the welfare assessment approach of the Welfare Quality® project, as well as other related research projects on broiler welfare. Animal-based measures can be effectively used to evaluate the welfare of broilers in relation to laws, codes of practice and management. Many of these are also appropriate for ante-mortem or post-mortem inspection of animals at the slaughterhouse.

It is concluded that the Welfare Quality® Broiler Protocol covers the majority of the main factors identified in the EFSA Scientific Opinion on broilers (EFSA, 2010a) and that animal-based measures are very useful to determine whether or not the improvements in welfare intended by the recommendations in the EFSA Opinion have been achieved. However, it is noted that some of the factors (e.g. poor ventilation) lack specificity, which means that there are several outcomes that could be measured, and also sometimes an animal-based measure (e.g. lameness) lacks specificity, which means a welfare outcome could have one or several causes. Thus, the links between factors (resources and management) and their welfare consequences (using animal-based outcome measures as indicators) is far from simple. Nevertheless, a "toolbox" of valid and reliable animal-based measures is described, from which the most appropriate measures or combination of measures can be selected. The selection will depend on which welfare outcomes (consequences) are to be assessed and the reason for wanting to assess them (e.g. whether part of a management/breeding strategy or to enforce legislation). Several animal-based measures listed in this Scientific Opinion are already fully developed and have a high potential for automation in commercial practice, as is already the case in some countries (e.g. detection and score of foot-pad dermatitis) and injury scores. Other animal-based

measures have been widely used for a longer time (e.g. automatic weight gain monitoring, feed and water consumption at flock level). Such data from the standardised use of some of these measures, in a variety of real life situations, could be collected on a regular basis and the database analysed to describe these complex associations. This would continually improve the selection process of appropriate animal-based measures for different contexts. It would also pave the way for a move towards quantitative risk assessment of broiler welfare.

There are several ways in which animal-based measures can be and are used to assess the welfare of broilers. Many of the animal-based measures that are referred to in this opinion are related directly or indirectly to the health and production of broilers as well as to specific environmental conditions (e.g. high temperatures, heat stress, panting). Most often, the indicators are used to identify animals whose welfare is already poor. Animal-based measures (such as panting), together with automatic surveillance systems, could be used to identify that welfare is being affected so that changes can be made before the consequences become too severe (e.g. early recognition of panting and increase of ventilation rate to avoid deaths attributable to heat stress). Thus, in monitoring and surveillance systems some animal-based measures may be useful, not only because they can indicate current welfare problems in the flock, but also because they can serve as a tool for early detection of consequences that may indicate a potential, future, negative situation. Although animal welfare issues can be addressed using animal-based measures, several situations in which a non-animal-based measure is preferable in practice have been identified. The most common reason is that there is a resource-based measure easier to record (e.g. elevated ambient temperature, high levels of atmospheric ammonia) or that the animal-based measure is too time-consuming to collect or requires specific skills or analysis. In some cases, no single measure is fully adequate.

The greatest potential to improve animal welfare in broiler production is seen in the application of a range of appropriate animal-based measures to be assessed and documented in the slaughterhouse in the course of visual meat inspection. Such measures can also be used to document welfare changes over time. This should include the development of automatic monitoring and assessment systems as well as both initial and ongoing training of assessors in the field and in the abattoir to ensure valid and reliable welfare measurement. There are currently no animal-based measures to use as welfare outcome indicators on-farm or in the slaughterhouse to assess the issues of pain, frustration, boredom and other positive and negative emotional states in the standard broiler. Research in this area is lacking. There are limited management options to prevent the negative consequences of factors arising from most housing-related problems with when the flock is still in the house. The same applies to negative effects arising from genetic selection. Changes in breeding goals may take a long time to improve welfare as indicated by animal-based measures noted at the farm level. Some factors, such as changing the litter or stocking density, can be made between flocks whereas others, such as changing the ventilation system, remain difficult even between flocks.

The probability of a feature in the environment becoming a hazard depends on the characteristics of the animal, including its genetics and its age. Therefore, animal-based measures, describing the consequences of animal exposure to factors, are the preferred indicators of animal welfare and should be used whenever possible in future EFSA risk assessments of broiler welfare. To facilitate this future work, there is a need for more systematic herd monitoring and surveillance programmes in the broiler industry.

Data on animal-based welfare-outcome indicators can be collected on-farm or at the slaughterhouse, provided that there is adequate traceability, either by observation or inspection of the animal, or from other sources, such as meat inspection, disease-reporting systems and production records. Furthermore, although welfare is a characteristic of the individual animal, many of the animal-based measures in broilers are in fact reported at the flock level. A list of potential animal-based measures is provided in this opinion. Benchmarking is increasingly used to track changes within the same farm over time or, more often, to compare farms. When the same animal-based measure is compared among farms with similar housing systems and management practices, it facilitates the identification

of those farms that are outside the normal range of variation and this information is also relevant to the assessment of broiler welfare.

TABLE OF CONTENTS

BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

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 broilers. Two main areas of action of the Community Action Plan on the Protection and Welfare of Animals 2006-2010[5] are *"upgrading existing minimum standards for animal protection and welfare ... " and "introducing standardised animal welfare indicators in order to classify the hierarchy of welfare standards applied ... ".*

Article 6 of Council Directive 2007/43/EC[6] laying down minimum rules for the protection of chickens kept for meat production requires the Commission to submit a report to the European Parliament and to the Council concerning the application of the Directive and its influence on the welfare of chickens, as well as the development of welfare indicators, on the basis of available data and taking into account new scientific evidence.

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[7]. The use of animal-based measures to assess animal welfare is relatively new, but diverse research projects focus on these now, and such measures are also considered in various assessment schemes. Previous assessments relied mainly on resource-based parameters. Animal-based measures aim to directly measure the actual welfare status of the animal and thus include the effect of resource as well as management factors.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

The Commission therefore considers it opportune to request EFSA to give an independent view on the animal-based measures for the welfare of broilers.

- Identify how animal-based measures could be used to ensure the fulfilment of the recommendations of the EFSA scientific opinions on the welfare of broilers.
- 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, and, where necessary, how other scientific information can be used to cover these hazards.
- Identify which relevant animal welfare issues cannot be assessed using animal-based measures for broilers and what kind of alternative solutions are available to improve the situation.
- List main factors in the various husbandry systems which have been scientifically proven to have negative effects on the welfare of broilers and to what extent these negative effects can be or not prevented through management.

The assessment should be based on, and linked to, the risk assessment of the previous EFSA scientific opinions.

[4] Council Directive 98/58/EC, of 20 July 1998, concerning the protection of animals kept for farming purposes. OJ L 221, 8.8.1998, p. 23-27.
[5] http://ec.europa.eu/food/animal/welfare/actionplan/actionplan_en.htm
[6] Council Directive 2007/43/EC, of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production. OJ L 182, 12.07.2007, p. 19-28.
[7] http://www.welfarequality.net/everyone/43148/9/0/22

ASSESSMENT

1. Introduction

This scientific opinion is an overview of the current and potential future use of animal-based measures to assess the welfare of broilers and is divided into three main sections. The first section presents the background to this work by outlying the previous EFSA scientific opinions in this area, the work on broiler welfare carried out within the EU-funded Welfare Quality® project and general issues related to the use of animal-based measures. The second section discusses the four terms of reference outlined in the mandate. A third section addresses ways in which data and information on the links between the factors affecting welfare and the measures used to assess welfare can best be merged to facilitate further developments in welfare assessment.

1.1. EFSA Scientific Opinions on the welfare of broilers including additional preparatory work to update those opinions and the Welfare Quality® research project

In 2010 the EFSA AHAW Panel published a Scientific Opinion on the influence of genetic parameters on welfare and resistance to stress of commercial broilers, and a Scientific Opinion on welfare aspects of management and housing of grand-parent and parent stock raised and kept for breeding purposes (EFSA, 2010a, b). For broilers, the major welfare concerns identified and associated with genetic selection were skeletal disorders leading to problems such as lameness, contact dermatitis, ascites and sudden death syndrome. These concerns are linked to fast growth rates and environmental conditions, although there are differences between countries, regions, and different farming systems. The expert report suggested that the welfare of broilers could be improved, particularly if birds are genetically selected to withstand the environment they live in. For example, as fast growing broilers are susceptible to heat stress, birds that grow more slowly should be selected for hot climates. Moreover, in the genetic selection of chickens, it was proposed that high priority should be given to decreasing the number of lame birds and reducing contact dermatitis whose causation involves genetic predisposition and environmental conditions such as wet litter (EFSA, 2010a).

The main objective of additional preparatory work (De Jong et al., 2012) was to update the information included in these two scientific opinions (EFSA, 2010a, b) as well as an earlier one on broiler welfare published by SCAHAW (SCAHAW, 2000). In particular, the aim was to review the literature provided in the opinions in order to identify gaps and potential areas to strengthen or amend the conclusions and recommendations of these opinions. The preparatory work also identified hazards that may be revised by the AHAW Panel in light of the newly available scientific evidence.

1.1.1. Preparatory work to update the EFSA scientific opinions on the welfare of broilers

The preparatory work used a step-wise iterative approach in which they involved experts from a number of different research institutes. An initial literature search resulted in a large number of abstracts that were screened for relevance to the report by the editorial team. Sixteen authors were recruited and were sent one or more paragraphs from the three previous scientific opinions, as well as abstracts related to these paragraphs. They were asked to apply their expertise and experience to add any missing references and additional knowledge, and to develop this into texts for each paragraph. The new draft paragraph texts were then sent to nine "first reviewers". These scientific reviewers received one or more paragraphs of the report and developed the texts further. They provided additional expertise or references. Subsequently, five "second reviewers" were asked to do the same as the first reviewers. Thereafter, the editorial team worked on the text and proposed a list of amended conclusions and recommendations, as well as an updated hazard list. All authors and reviewers received the report in its final version to allow for any further comments on the text.

Databases searched included ISI Web of Knowledge (all databases, i.e. Web of Science, Current Contents Connect and Medline) and CAB Abstracts. General searches were conducted on broiler welfare as of (and including) the year 2000 and onwards using the key words broiler*, chick*,

poultry*, welfare. More specific searches using other key words were conducted when only a few references were initially found for a certain topic.

The results of the literature review were reported in three sub-reports, each updating a previous EFSA/SCAHAW opinion and summarising the new information since the previous SCAHAW/EFSA scientific opinions were published. Only the sub-report referring to the EFSA scientific opinion on the influence of genetics on the welfare and the resistance to stress of commercial broilers (EFSA, 2010a) is presented in detail here. The information in the other reports is also used in this scientific opinion. For details on the contents of the other sub-reports we refer to De Jong et al., 2012.

For the sub-report dealing with the EFSA scientific opinion on broilers (EFSA, 2010a), nine new conclusions were suggested. These were: i) there are some indications that incubation conditions may affect leg health, but further research is necessary; ii) gait score is widely used to assess broiler leg health in commercial flocks. However, gait score cannot discriminate between underlying pathology or poor gait due to conformation; iii) because of the relationship with management factors, flock health and the fact that foot and hock lesions are likely to be painful, foot-pad dermatitis (FPD) and hock burns are useful welfare indicators in broilers; iv) hock and foot lesions likely have a partially different aetiology, where hock lesions are not only related to wet litter and ammonia concentrations in the litter (like FPD) but also to the weight of the birds; v) diet composition may affect the incidence of ascites; vi) the brooding process may affect the incidence of ascites post-hatching; vii) low energy intake can decrease the incidence of sudden death syndrome (SDS) and ascites because of a slower growth rate; viii) brooding conditions may affect the ability of the animal to cope with heat stress later in life; and iv) suboptimal digestibility of feed may have a negative effect on litter quality and in this way affect the cleanliness of the birds and the incidence of contact dermatitis (De Jong et al., 2012).

Recommendations of the previous EFSA report are further supported by new information. One new recommendation was the suggestion to further study the role of incubation conditions on welfare issues such as gait abnormalities, thermal discomfort and ascites (De Jong et al., 2012).

Some new hazards are proposed and the evidence behind many already identified hazards was strengthened (for details see section 2.2.2 and Table 4).

1.1.2. The Welfare Quality® project

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 EFSA opinions in that it did not aim to identify risk factors that were associated with good or poor welfare. The project focused primarily on animal-based indicators that could be monitored and used during inspection to assess current levels of welfare (Keeling, 2009). Welfare Quality® proposed four welfare principles, good feeding, good housing, good health, and appropriate behaviour, linked to 12 criteria that result in good welfare (Blokhuis et al., 2010). The 12 Welfare Quality® criteria include: absence of prolonged hunger and thirst, comfort in relation to resting, thermal conditions and ease of movement, absence of injuries, disease and pain, expression of social and other behaviour, good human-animal relationship and positive emotional state. These welfare criteria were in turn linked, in the detailed Welfare Quality® broiler chicken protocol, to a series of welfare measures, such as those related to body condition, lameness, injuries and lesions, avoidance distance test (touch test), and free range access (Forkman and Keeling, 2009; Welfare Quality®, 2009).

1.1.3. Terminology and integration of concepts

The concepts of animal welfare used by the Welfare Quality® project and the EFSA opinion overlap considerably. In addition, the measures of welfare used in the Welfare Quality® broiler chicken protocol have links to main welfare issues addressed in the previous EFSA scientific opinion (EFSA, 2010a). The main exception being that Welfare Quality® included more signs of good welfare (i.e.

positive emotional state) than the EFSA opinion which was mandated to be focused on negative states in their risk assessment. The Welfare Quality® project specifically addressed the relationship between measures within and between the different welfare criteria, and in the EFSA scientific opinions the relationships between risk factors are discussed. Nevertheless, neither Welfare Quality nor the EFSA Scientific opinions before 2012 systematically linked risk factors and their welfare consequences (see EFSA, 2012a). General issues that arose during the development of the scientific opinions on the use of animal-based measures to assess the welfare of dairy cattle and pigs have been discussed in an EFSA statement (2012d) and so will not be discussed here unless specifically related to broiler welfare. However, there are some terms that should be clarified.

In the previous EFSA Scientific Opinion on the influence of genetics on the welfare and the resistance to stress of commercial broilers (EFSA, 2010a), the word "hazard" was used to mean something that increased the risk of impaired welfare and, therefore, it is also used in the request 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 (EFSA, 2012a). Thus, in this opinion, the word "factor" is used and can be considered as synonymous with "hazard" when applied to factors that have the potential only to impair welfare. Depending on the characteristics of the broiler (hybrid, sex, age, etc.) these factors have consequences for welfare. In previous opinions the consequences that have been assessed have focused on the negative and so the term "adverse effects" has been used. However in keeping with the move towards assessing both risks and benefits, it is recommended that the term "consequence" is used (EFSA, 2012a). Thus, in this opinion the word "consequence" is used and can be generally considered synonymous with "adverse effect". A last point of clarification is that 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 a skin injury, percentage of lame or unusually slow growing birds, high mortality rate). The terms "welfare outcome indicator" and even simply "outcomes" are also sometimes used in animal welfare science for major changes in animal-based measures that clearly indicate that welfare has been affected.

Much of the research relevant to this opinion addresses the need to identify valid and robust outcome-based indicators of broiler welfare and, wherever possible to recommend reliable measurements to be used when scoring responses (e.g. foot-pad dermatitis or heat stress). However, the decision as to what is, and what is not, acceptable is a matter of ethics and can be expected to vary according to human values and attitudes towards animal welfare. Our aim is to ensure that ethical decisions concerning the acceptability of husbandry inputs (resources and management) and about welfare outcomes are based on sound scientific evidence.

1.2. Essential attributes, selection and uses of animal-based measures

In many respects the issues relevant to the animal-based measures used to assess broiler welfare are comparable with those used for any diagnostic test. We use these terms in specific contexts, but it is suggested that the criteria applied to diagnostic tests could also be applied to animal-based measures (EFSA, 2012d). For example *fitness for purpose* means that the test methods and related procedures must be appropriate (properly validated) in view of a specific purpose. *Validation*, in the context of this scientific opinion refers to the diagnostic performance of the measure i.e. diagnostic *sensitivity* and *specificity*. When combined this is sometimes referred to as *accuracy*, which in a welfare context would be comparable to the overall correctness of an animal-based measure to identify a specific welfare consequence.

Robustness is another essential attribute of an appropriate animal-based measure for the assessment of animal welfare. It influences how the measure is affected by changes in the environment, who is taking the measure and when it is taken. It encompasses concepts such as *repeatability* and *reliability*, which are the agreement between repeated measurements of the welfare consequence on the same sample by the same (intra-observer) or different assessor (inter-observer) respectively. Maintaining repeatability and reliability over time requires training at regular intervals so that observers are

"recalibrated" to a reference standard for the measure. This is very important to promote harmonization of recording to ensure consistency and accuracy of measurements. Whenever welfare outcomes vary over time, for example if they vary according to season, time of day, or time interval since last feeding, then the measures should be based on a representative time sample.

Welfare is a characteristic of the individual at a stated time, and most animal-based measures are taken on individual animals. However, in the case of broilers, individual animal data are normally aggregated to a flock, farm or population level, using summary measures, such as proportions or means, and interpreted against predefined threshold values. Whenever measures are taken from only a sample of all animals in the unit, it is essential that the sample should be unbiased and representative (e.g. in terms of sex, body size, location in the building etc.). It is important to specify how the sample of animals is to be chosen and the number of animals in the sample. The use of good operating procedures and reporting standards developed in health research should be applied to all animal-based measures.

In order to obtain information about the welfare of the birds in a flock, using animal-based measures, it is necessary to select a sufficient number of birds and samples that are representative for the purpose of the assessment. On-farm assessment has to be conducted at an appropriate time.

These measures may be categorised as follows:

- Animal-based measures:
  - *Observations and measures:* from the animals made during the welfare assessment on-farm, ante- or post-mortem and are direct indicators (e.g. behaviour, clinical signs of injury or lameness, contact dermatitis). Some are veterinary procedures that can carried out only by a veterinarian or other authorised individual (e.g. post-mortem inspection – septicaemia, hepatitis, bruises, skin and lung lesions, ascites, contact dermatitis);
  - *Flock records* (body weight, disease records, mortality, etc.): are indirect and overarching indicators and are usually not taken from individual birds and may include records of animal-based measures obtained using automated methods (e.g. automatic weight recording). Automatic recording of activity has been developed under experimental conditions and should be tested under field conditions, because is a potential future method of considerable promise.
- Non-animal-based measures (resource- and management-based):
  - *Observations and measures:* of housing provided, management used (e.g. quality of bedding, stocking density, air quality, environmental temperature, efficiency of ventilation system), biosecurity (e.g. hygiene routines for stockmen and visitors, pest control; between flocks: removal of litter, cleaning and disinfection) and health control (prophylactic measures in terms of vaccination and antiparasitic treatment and medical treatment when justified).
  - *Documentation:* (e.g. biosecurity records, feed delivery, feeding programmes, lighting programmes, checking back up systems, bird origin and delivery, staff training).

1.2.1. Uses of animal-based measures

The scientific opinions dealing with the use of animal-based measures to assess dairy cattle and pig welfare (EFSA, 2012b, c) came to the conclusion that it was unrealistic and also unnecessary to recruit *all* of the measures identified by the experts on every occasion that the welfare of the animal is to be assessed. They considered the list a "toolbox", from which to select the measures necessary to address the specific objectives of a particular assessment. The same can be expected in this scientific opinion.

The animal-based measures highlighted in this opinion should be defined according to standard operating procedures leading to more detail about how to carry them out. This has already been undertaken for the measures in the Welfare Quality® poultry protocol (Welfare Quality®, 2009).

Furthermore, a defined set of animal-based measures is needed to provide a baseline or benchmark for comparison over time. Such benchmarking of a harmonised set of standardised animal-based measures is essential to confirm improvements in broiler welfare following a change in genetic selection or the environment. Some of the changes in broiler management that would be needed in order to improve welfare can be implemented in a period of hours or days, but others may take weeks or months to achieve. For example, changes in buildings such as a new ventilation system may be carried out only between batches of birds and changes in the genetic selection objectives may take several years to achieve a significant change in commercial broiler flocks (see section 2.4).

Within the EU there is increasing emphasis on changing the official control measures to reflect the estimated risk. This is specified within the "hygiene package" legislation (Regulation (EC) No 882/2004[8]) to verify compliance with animal disease control and welfare rules. It is stated that the frequency with which these official controls of animal health and welfare are carried out shall be proportional to the risk, which is called target inspection or risk-based inspection or surveillance.

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

- By a manager or advisor of a farm or company to monitor his/her management decisions.
- By an auditing or accreditation organisation to check that a farm satisfies the necessary criteria to be part of a quality assurance or labelling scheme.
- By the competent/responsible authority to check that a farm satisfies animal welfare requirements according to legislation, and evaluate effects in practice of changes in animal welfare legislation.
- By the competent/responsible authority as part of pre-testing the welfare consequences of any future housing or technical development before it is approved for general use.
- By scientists during an experiment, so that their results can be compared with the results collected by other scientists.
- By farmers to check that its farm satisfies animal welfare requirements and to track changes as a result of changes in management or environment.
- By veterinary practitioners involved in flock health management.

2. Addressing the terms of reference

This section deals with the four terms of reference (ToRs). Each of the following sections follows the same structure; first, the procedures used to address that particular ToR; second, the results are presented and, finally, there is a discussion of the main findings.

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 broilers (ToR 1)

In the earlier scientific opinions in this series on the use of animal-based measures to assess the welfare of dairy cattle and pigs (EFSA, 2012b, c), recommendations were phrased in terms of the

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

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. This means that even the fact that a recommendation from the EFSA Scientific Opinion (EFSA, 2010a) was fulfilled (i.e. the resource was provided), does not necessarily mean that the intended welfare improvement for the animal was achieved and vice versa. This is not the case for the most recent EFSA opinions on the welfare of broilers and broiler breeders (EFSA 2010a, b). In these opinions the majority of recommendations are already phrased in terms of animal-based measures. This made it considerably easier to address this ToR. The specific formulation of the recommendation determines what type of measure (animal-, resource- or management- based) should be used to ensure the fulfilment of the recommendation, and this should be considered when formulating recommendations in future.

2.1.1. Procedures to address this question

The focus has been on which measures may be implemented and what aspects should be considered when deciding whether or not to implement them. Some of these points were already dealt with in the section on essential attributes of animal-based measures (see section 1.2).

Each of the 23 recommendations in the EFSA Scientific Opinion on the influence of genetics on the welfare and the resistance to stress of commercial broilers (EFSA, 2010a) was considered in turn to determine animal-based measures that would be appropriate to evaluate whether or not the recommendation is being fulfilled, and so lead to better welfare on the farm (Appendix A). In compiling the list, measures were associated with the EFSA recommendations, where this was possible. . As the EFSA report was focussed on the influence of genetics on the welfare of broilers, there were in this report some general recommendations on genetic selection and interaction with the environment (recommendations 16 to 23). For these recommendations, it was impossible to allocate potential animal-based measures to them. Furthermore, we added in the table welfare consequences more specifically related to environmental, and management factors, that had not been addressed in the EFSA opinion (kerato-conjunctivitis, functional development of the eyes, tracheitis, cold stress, disturbance of resting, fear and its deleterious effects, injuries such as bruising and fractures) and in the Council Directive 2007/43/EC (parasitic infections).

The preparatory work (De Jong et al., 2012; see also section 1.1.1) defined updated and new recommendations related to the update of the previous SCAHAW (2000) and EFSA (2010a) reports. In the update of the EFSA (2010a) report these new recommendations were related only to the need for future research and are therefore not included in Appendix A. In the update of the SCAHAW (2000) report several new or modified recommendations were presented. Where these are related to the animal-based measures in Table 1, they are referred to in Appendix A in a separate column.

Efforts have been made to propose measures that can be recorded by a veterinary or other inspector on-farm. However, many of these measures are also appropriate for ante-mortem or post-mortem inspection of the animal at the slaughterhouse. Some measures that cannot be used easily on-farm have been added for their potential interest in the future (e.g. digital motion detection, motivation for activity).

2.1.2. Main findings and issues

Results are presented in Appendix A and summarised in Table 1.

Table 1: List of animal-based measures used in Welfare Quality® or proposed from other sources for welfare consequences addressed by previous EFSA recommendations[#] (EFSA; 2010a).

Consequence	Available animal-based measures[§]	
	Welfare Quality® (2009)	**From other sources**
Mortality[ç]	-Culls on-farm (F) -On-farm mortality (F)	-Found dead[ç] (F) -First week mortality[ç] (F)

		-Cumulative daily mortality rate: Council Directive 2007/43/EC (F) -Daily mortality rate[ς] (F)
Musculoskeletal disorders (infectious, developmental, degenerative)[ς]	-Gait score[ς] (F)	-Gait analysis: Reiter and Bessei, 1997; Stojcic and Bessei, 2009 (F) -Digital motion detections: Dawkins et al., 2009; Kristensen and Cornou, 2011 (F) -Anatomical and pathological changes: Butterworth and Arnould, 2009 (F/S) -Automated activity recording: Aydin et al., 2010 (F) -Latency to lie test (waterbath test): Weeks et al., 2002 (F), modified latency to lie test: Berg and Sanotra, 2003 (F) -Force plate assessment: Sandilands et al., 2011 (F), For review see Butterworth and Arnould, 2009
Muscle disorders: myopathies (deep pectoral myopathy, muscular dystrophy) and muscle damage[ς]		-Biochemical indices of muscle damage[ς]: Sandercock et al., 2009; McRae et al., 2006; Dinev and Kanakov, 2011 (F/S) -Anatomical and pathological changes, autopsy: Gregory, 1998 (F/S)
Contact dermatitis[ς]	-Breast burns (F/S) -Hock burns (F/S) -Foot-pad dermatitis (F/S)	-Foot-pad lesions: Ekstrand et al., 1998; Michel et al., in press (F/S) -Contact dermatitis: Allain et al., 2009 ; for review Arnould et al., 2009 (F/S)
Skin disease	Breast blisters (F/S)	Breast blisters: for review Arnould et al., 2009 (F/S)
Ascites, pericarditis, sudden death syndrome and spiking mortality syndrome[ς]		-Anatomical and pathological changes, post-mortem inspection, autopsy: Gupta, 2011 (F/S) -Found dead, mortality, daily mortality rate: Council Directive 2007/43/EC (F)
Respiratory and mucous membrane diseases (infectious and environmental origin)[ς]		-Mortality (F) -Morbidity (F) -Anatomical and pathological changes, post mortem inspection: Aziz and Barnes, 2010 (F/S)
Thermal discomfort (heat stress)[ς]	Panting[ς] (F)	-Panting[ς]: McLean et al., 2002 (F) -Space distribution: Arnould and Faure, 2004 (F)
Thermal discomfort (cold stress)[ς]	Huddling (F)	
Behavioural restriction[ς]	-Qualitative behavioural assessment (QBA) (F) -Plumage cleanliness (F/S)	-Mobility (digital motion detections): Aydin et al., 2010; Kristensen and Cornou, 2011 (F) -Leg problems (see above musculoskeletal disorders) -Motivation for activity: Bokkers and Koene, 2004 (F) -Duration of bouts of different behaviours: e.g., Febrer et al., 2006; Buijs et al., 2010 (F) -Distance walked per unit of time: Leone and Estevez, 2008a, b (F)

		-"Bird compression" (actual a minimum space occupied by birds): Bokkers et al., 2011 (F)
Fear (SCAHAW, 2000)	Avoidance distance test (ADT)	-Fear measures (avoidance distance test, touch test, novel object test): Forkman et al., 2009 (F)
Hunger		-Body weight (F/S) -Growth rate, feed consumption (F)
Thirst	Dehydration measures (shank skin chicks) (F/S)	-Water consumption (F) -Dehydration measures (shank skin chicks): Butterworth and Niebuhr, 2009 (F/S), -Voluntary water consumption: Sprenger et al., 2009 (F)
Digestive dysfunction[ç]	Plumage cleanliness (F/S)	Excreta quality (diarrhoea) (F)
Emaciation	Emaciation (F/S)	Weight, body condition (F/S)
Injuries	-Plumage damage (feather pecking; laying hen protocol) (F/S) - Comb pecking wounds (laying hen protocol) (F/S)	-Scratches, wounds, bruising: Allain et al., 2009 (F/S) -Broken wing bones, broken legs: Butterworth and Niebuhr, 2009; Knierim and Gocke, 2003 (F/S) -Aggressive behaviour: Cornetto et al., 2002; Ventura et al., 2012 (F) -Culling due to injuries (F)
Other diseases (infectious and non infectious)	-Eye pathologies (laying hen protocol) (F/S) -Parasites (laying hen protocol) (F/S) -Septicaemia (F/S) -Hepatitis (F/S) -Abscesses (sub-cutaneus pus) (F/S)	-Eye irritations and abnormalities (F/S) -Parasitic infections (ecto-parasites, endo-parasites) (F/S) -Septicaemia (F/S) -Hepatitis (F/S) For review, Gregory, 1998; Butterworth and Niebuhr, 2009

Text highlighted in grey concerns the consequences that are not covered by recommendations of the previous EFSA Scientific Opinion (EFSA, 2010a).

§ Letters in parenthesis refer to a measure made on-farm (F) or on-farm and at the slaughter house (F/S).

ç EFSA (2010a).

In most cases, the animal-based measures are made on a sample of individual animals and interpreted at the farm, flock or group level (e.g. percentage of animals with severe foot-pad dermatitis). However, it was not the intention, nor was it possible within these tables, to describe how the individual observations and measures should be made or how they should be interpreted in the assessment of welfare outcomes, since this will depend on the purpose of the assessment. The volume of published scientific evidence and sound clinical practice underpinning the methodology for recording and interpreting these indicators is, in most cases, very large. Table l presents a comprehensive list of all animal-based measures. The list can be regarded as a "toolbox" from which potential measures can be selected. In most cases, directions for those seeking further details of methodology and interpretation can be obtained in the first instance from comprehensive review publications (Welfare Quality®, 2009; EFSA, 2010a). Original communications are quoted when they provide a self-sufficient account of what the measure is, as well as the methodology and interpretation. Some, but not all, animal-based measures have already been tested for validity (accuracy and precision), reliability (repeatability, reproducibility and robustness) and feasibility (practicality and cost). It is recommended that animal-based measures are evaluated on these essential attributes before

being added to the toolbox and before being used in practice to assess the welfare of broilers, so that informed decisions can be taken on their use in different contexts.

2.1.3. Discussion

Whereas all of the recommendations of the EFSA report on genetic selection and the welfare of broiler chickens can be addressed by animal-based measures, some of them are not practical for use in commercial flocks of standard broilers addressed in the mandate (e.g. force plate analysis of lameness, biochemical indices of muscle pathology). Furthermore, some measures have not been validated for the intended purpose (e.g. Qualitative Behaviour Assessment, see below).

Certain measures such as foot-pad dermatitis, breast blisters and hock burn are described as painful although the evidence for this may be uncertain, we expect these conditions to be at least potentially painful because of the pathology associated with them. The reliability and repeatability of several measures are not known and are sensitive to characteristics of the individual such as age (e.g. lameness) or broilers line and intra- and inter-observer reliability (e.g. gait score).

Some animal-based measures are not thought to be currently useful for assessing welfare but may become so in future. For example, some consequences are of such a low occurrence that animal-based measures are not useful in practice although they have been included here for completeness. This is particularly true if slow-growing broilers and alternative systems of production are more widely used. Examples of animal-based measures that may be useful for assessing older broilers include measures of aggression and feather pecking, feather pulling and integument damage, and cannibalism. Broken bones wings occur in standard broilers largely as a consequence of capture and transport but the incidence may increase in future in alternative systems of production as a result greater activity and collisions with enrichment items.

Animal-based measures taken at slaughterhouses should not be affected by catching, transport or slaughtering conditions (e.g. waiting before slaughtering) if they have to be used to assess the welfare of broilers on-farm e.g. foot-pad dermatitis is not influenced by catching and transport whereas broken wing bones and bruising are.

An important issue addressed in ToR 1 relates to the use of animal-based measures to fulfil the recommendations of the EFSA (2010a) scientific opinion on genetic aspects of the welfare of broilers. The main concerns identified in the EFSA (2010a) scientific opinion (skeleton disorders, contact dermatitis, acites and sudden death syndrome) were also the issues for which animal-based measures are identified in the current report, e.g. measures of lameness, foot-pad dermatitis and mortality. The lack of co-ordinated data collection precluded objective assessment of the importance of genetic selection and broiler welfare in the 2010 report. The systematic collection, collation and summary of the major animal-based measures identified in this report will facilitate the assessment of trends with time of critically important traits that determine the welfare of broilers. Some animal-based measures have a large environmental component in addition to a genetic predisposition and it is inappropriate to attribute the cause solely to genetic change. The systematic assessment of changes over time, the importance of which was noted in the previous EFSA report (EFSA, 2010a), would involve both producers and breeders in monitoring trends in welfare indicators. Such a scheme would provide objective evidence on both the welfare of broiler chickens and the success or otherwise of claims of genetic improvement in welfare traits as a result of genetic selection for improved welfare.

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 broiler chicken assessment protocol suggested by the Welfare Quality® project covers the main input factors (hazards) identified in the EFSA Scientific

Opinion (EFSA, 2010a) on the influence of genetic parameters on the welfares and the resistance to stress of commercial broilers and how the input factors in the EFSA opinion address the issues raised in Welfare Quality® and therefore addressed in its protocols (Welfare Quality®, 2009).

In the original EFSA opinion (EFSA, 2010a), 13 unique factors were identified. But since a particular factor may lead to/cause several different consequences (adverse effects), the risk assessment was based on a total of 47 factor characterisations.

The measures in the Welfare Quality® broiler assessment protocols include measures taken on-farm and measures recorded at the slaughterhouse that indicate something about the welfare of the birds on the farm. The broiler protocol also includes resource-based measures. For ease of analysis and since this opinion focuses mainly on the use of animal-based measures, these were analysed separately. Animal-based measures are presented in Appendices B and C whereas resource- and management-based measures are presented in Appendix D. In these tables the 47 unique factor characterisations from the EFSA scientific opinion (EFSA, 2010a) are presented in the rows, whereas the columns show the Welfare Quality® broiler assessment measures. There are 17 animal-based measures in Appendices B and C and 4 management or resource-based measures in Appendix D.

For each animal-based measure two separate scores ranging between 0 and 4 were assigned, one score for specificity (Appendix B) and one for sensitivity (Appendix C) of each animal-based measure with respect to each consequence. This scale represents none, low, medium, high and very high sensitivity or specificity. The scores were given individually by the members of working group and the two attributes were scored separately. Results were then discussed and a final score for each attribute agreed during meetings and telephone conferences.

Sensitivity was defined as the probability that the consequence is detected by the animal-based measure (i.e. probability of a correct positive test). A score of 0, or a low score, implies no or little sensitivity and a poor chance that the animal-based measure will detect the consequence if it is there, whereas a high score implies there is good chance of detecting it.

Specificity was defined as the degree with which the animal-based measure is related to a single welfare consequence or whether it relates (responds) to several different consequences. In other words, a low score implies low specificity, indicating that the animal-based measure could be the response of many welfare consequences, and a high score (high specificity) indicates that the measure is a response to one or very few consequences.

As a general guideline, animal-based indicators with adequate sensitivity but low specificity can be used for screening to identify flocks with welfare problems. These non-specific animal-based measures have been called "iceberg indicators" (FAWC, 2009). If a flock is identified as likely to have welfare problems, a larger set of animal-based measures with adequate sensitivity and specificity should be used to assess more accurately the welfare level and to identify the main consequences that are leading to the poor welfare. However, to achieve the goal of addressing the problem, a set of animal-based measures with high specificity for the consequences with the largest welfare impact identified in the previous step, but still with adequate sensitivity, should be used to monitor the effectiveness of the intervention.

In the Welfare Quality® protocol qualitative behavioural assessment (QBA) is carried out by observing target individuals in a flock and using descriptors for their behaviour, such as "calm", "aggressive", or "sociable". QBA has been investigated in dairy cattle, pigs, and laying hens but has not been validated in broiler chickens. For this reason it was not scored for specificity and sensitivity in this scientific opinion. However, recent research (DEFRA project AW1143) has used QBA to assess individual broilers of different gaits and with different leg health pathologies, and the results indicate that differences between birds are detectable with this method. For this reason QBA is still included as a potential animal-based measure and included in the discussion in this opinion.

When completing the tables for ToR 2, it was considered that both breast blister and breast burn can be measured using the Welfare Quality® protocol (see section 2.2.3) even if only the term breast blister is used in the Welfare Quality® protocol.

Following the completion of the Appendices B and C, network diagrams were created to show: (i) the strength of the link between a factor and a consequence, and (ii) the strength of the link between a consequence and each of the Welfare Quality® broiler protocol animal-based measures. This was done to allow the members of the working group to follow the link from the factor through to the animal-based measure and understand how well the two are associated, if at all.

The first key piece of information required to create the network diagrams was the probability of occurrence of consequence in the presence of a factor. This value, expressed originally as a percentage (%) in the 2010 risk assessment of the welfare implications of the genetics of broilers (EFSA, 2010a), for visual presentation, it was converted into a 4 category variable, *P* ($P < 20\% = 1$; $20\% \leq P < 40\% = 2$; $40\% \leq P < 60\% = 3$; $P \geq 60\% = 4$). This categorical variable was used to determine the width of the line linking a factor and a consequence, with the widest lines representing the highest values of *P*. Note that links were quantified between factors and consequences only if they were identified as associated in the 2010 risk assessment (EFSA, 2010a). Where a consequence was not considered to be linked to a particular factor, no probability value (and hence no *P*) was ascribed. Basing the links on the left side of the figure on the original risk analyses meant that the new factors identified in the preparatory work (De Jong et al., 2012) could not be included.

The second key piece of information required to create the network diagrams was the strength of association between a consequence and an animal-based measure. Strength of association was assessed on the basis of both sensitivity and specificity by the members of the working group, and thus each possible combination of consequence and animal-based measure was given two scores: a specificity score (from 0 to 4) and a sensitivity score (from 0 to 4; see Appendices B and C). These scores were used to determine the width of the line linking a consequence and an animal-based measure, with the widest lines representing the strongest associations supported by strong scientific evidence.

The third piece of information used to create the network diagrams was a binary link between different factors. This does not quantify the strength of association between two non-independent factors, but simply highlights that the two factors tend to co-occur, or that the occurrence of one may lead to the occurrence of the other, e.g. "poor ventilation" and "wet litter". This binary link (yes/no) was decided by the members of the working group following discussion.

In the preparatory work (De Jong et al., 2012) an updated list of factors was provided related to the update of the EFSA (2010a) report. No factors were identified in the SCAHAW (2000) report. Therefore the preparatory work defined a list of factors related to the recommendations in the update of the SCAHAW (2000) report. A few of these factors were not previously identified in the EFSA (2010a) report.

2.2.2. Main findings and issues

Figures 1 and 2 show the network diagrams arising from this work. It is not necessary to focus on all the factors, consequences or animal-based measures and their links at this stage, but only to note the overall pattern. For this reason, although all *P* links (probability of occurrence of consequence in the presence of a factor) are shown in the network diagrams, for clarity, not all specificity (Figure 1) and sensitivity (Figure 2) links (between consequences and animal-based measures) are shown, only those specificity associations with a score ≥ 1; and those sensitivity associations with a score ≥ 2, respectively. The overall patterns are similar for both Figures 1 and 2 and so will be discussed together in this section.

To address the ToR 2, the Figures 1 and 2 should be read from right to left (how the assessment protocols suggested by the Welfare Quality® project cover the main factors identified in the EFSA scientific opinions) and from left to right (vice-versa).

A first point to notice is that many consequences are not linked to an animal-based measure from the Welfare Quality® broiler protocol. In terms of ToR 2, this means that there are factors identified in the EFSA scientific opinion (EFSA, 2010a) that are not covered by the animal-based measures in the Welfare Quality® protocol. These boxes are coloured in grey and examples include e.g. "movement restriction", "reduced behavioural repertoire" and "injury (contact with other birds or with physical structures)" etc. However, as said previously, the Welfare Quality® protocol also records some resource- and management-based measures. These are shown in Appendix D. All the consequences that were not associated with an animal-based measure, were judged by the working group to be covered by at least one of the four non-animal-based measures, usually the "stocking density" or "wet litter measures".

A second point is that, even if there are links between consequences and animal-based measures, they tend to be weak. The most common strength was "2" which implies only a medium chance that the animal-based measure is a response to a specific consequence (specificity) or, alternatively, a medium chance that the animal-based measure will detect the consequence (sensitivity), if it is there. There were very few specificity and sensitivity links with level "3" (high) or "4" (very high). This means that for links with level < 3, they are likely to be false positives (implying there is a consequence when there is not) and false negatives (the animal-based measure implies there is no problem when there is).Those consequences that do have strong links to particular animal-based measures can generally be thought of as being related to management e.g. heat stress, reduced litter quality, pain caused by hock burn, foot-pad dermatitis, breast burn which are caused by poor litter quality, and so on. The possibility to manage factors and therefore their consequences is discussed under section 2.4. It is not possible to discuss the strength of the link to the non-animal-based measures since here only a binary link, yes/no was given.

A final point is that there are three factors ("barren environments", "high light intensity" and "long cycle/photoperiod") that are not associated with any Welfare Quality® animal-based measures, although each of these factors have many consequences. However, none of these three factors is covered by non-animal-based measures in the Welfare Quality® protocol either. Thus these factors and their associated consequence(s) are not covered at all by the Welfare Quality® broiler protocol.

A strong specificity and sensitivity link was found between "panting" and "hyperthermia/heat stress" indicating that if "panting" is observed, "hyperthermia/heat stress" is very likely to be present in the flock. Note that "on-farm mortality" and "dehydration" measures are also linked with "hyperthermia/heat stress", but specificity is lower, thus giving little indication of which consequence is present. Even though occurrence of "panting" indicates the presence of "hyperthermia/heat stress", when trying to identify which factor is causing the heat stress it is difficult as "high temperature and humidity", "high stocking density" as well as "poor ventilation" all have low probability links with "hyperthermia/heat stress".

Similarly, "hock burn" and "foot-pad dermatitis" measures have high specificity and sensitivity with the consequences "pain from hock burn" and "pain from foot-pad dermatitis", respectively. These consequences, in turn, have strong probability links to factor "wet litter". In the case of "breast blisters" (both breast blisters and breast burns - see section 2.2.3), there is strong specificity and sensitivity links with the consequence "pain from breast burn" but lower specificity and sensitivity with the consequences "reduced activity" and "increased time in contact with litter" (see also Appendices B and C). If the animal-based measures "hock burn" and "foot-pad dermatitis" are recorded, the consequence "reduced litter quality" is present in the flock and the most likely risk factor responsible (highest probability) for this is "high stocking density".

The animal-based measure "plumage cleanliness" has very strong specificity and sensitivity with the consequence "dirty plumage". However, identifying the most likely risk factor responsible for this is difficult because, looking at the left side of the diagram, there is only a low probability link between "dirty plumage" and the risk factor "inappropriate diet".

Yet another animal-based measure with strong links to several consequences is the measure of "lameness" (in Welfare Quality® this is a gait score), which is strongly correlated with "lameness" (presumably painful), "leg weakness" and "skeletal disorders". The consequence "lameness" is then very strongly linked to the factor "unbalanced body conformation". Finally, the animal-based measure "ascites" (the diagnosis) is very strongly linked to the consequence "ascites" (the metabolic disease).

Less strong links are seen e.g. between the animal-based measure "culls on-farm" and the consequence "pain" (birds judged by the stockperson to be in pain), and between "emaciation" and "dehydration" and the consequence "reduced ability to reach feed/water when motivated".

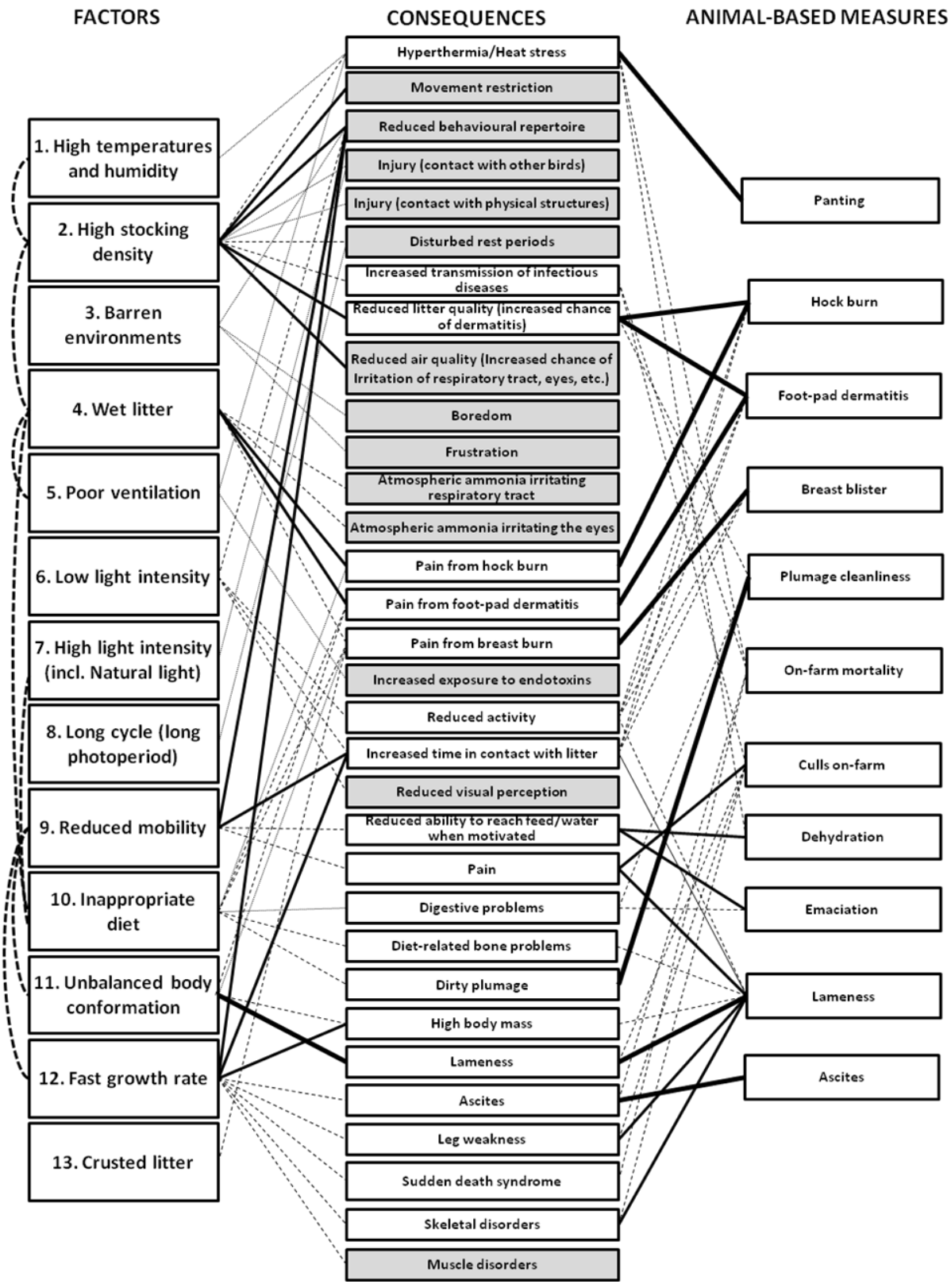
The animal-based measures "on-farm mortality" and "culls on-farm" have good sensitivity but low specificity with many consequences. For example, "on-farm mortality", has links with low specificity and high sensitivity to many consequences, such as: "hyperthermia/heat stress", "sudden death syndrome", "high body mass", "ascites", lameness" and "high body mass" (see also Appendices B and C)**"**. This can be explained by the fact that "on-farm mortality" and "culls on-farm", as an animal-based measure, do not simply reflect only one or few negative consequences, but many consequences linked to many risk factors. This is why these types of animal-based measures are more appropriate for screening flocks with welfare problems, but less appropriate for identifying the major welfare consequences or the risk factors causing them.

There are quite a number of other weak specificity relationships between various animal-based measures and consequences which came out of the literature review, but these consequences are rare on commercial farms in practice or not been studied a lot.

There are possible interactions between factors and some of the most likely two-way interactions were identified and are depicted on the left side of Figures 1 and 2, with broken curved lines. For example, there are likely interactions between "high stocking density" and "wet litter", between "wet litter" and "poor ventilation" and "inappropriate diet", between "reduced mobility" and "low light intensity", "unbalanced body conformation" and "fast growth rate". Though these interactions are important, they were not addressed in this opinion.

The following animal-based measures have 0 or low specificity and sensitivity with respect to any of the welfare consequences: huddling, septicaemia, hepatitis, pericarditis, abscesses, and the avoidance distance test (see Appendices B and C).
Some of the consequences also have no associated animal-based measure with adequate specificity (score < 1) and sensitivity (score < 2). These consequences, shown in grey in Figures 1 and 2, are: "movement restriction", "reduced behavioural repertoire", "injury through contact with other birds or physical structures", "disturbed rest periods", "reduced air quality" "boredom", "frustration", "atmospheric ammonia irritating the respiratory tract and eyes", increased exposure to endotoxins, "reduced visual perception" and "muscle disorders".

Figure 1: Diagram highlighting associations between Factors and Consequences (focusing on risk), and between Consequences and Animal-Based Measures (focusing on specificity), in broiler welfare.

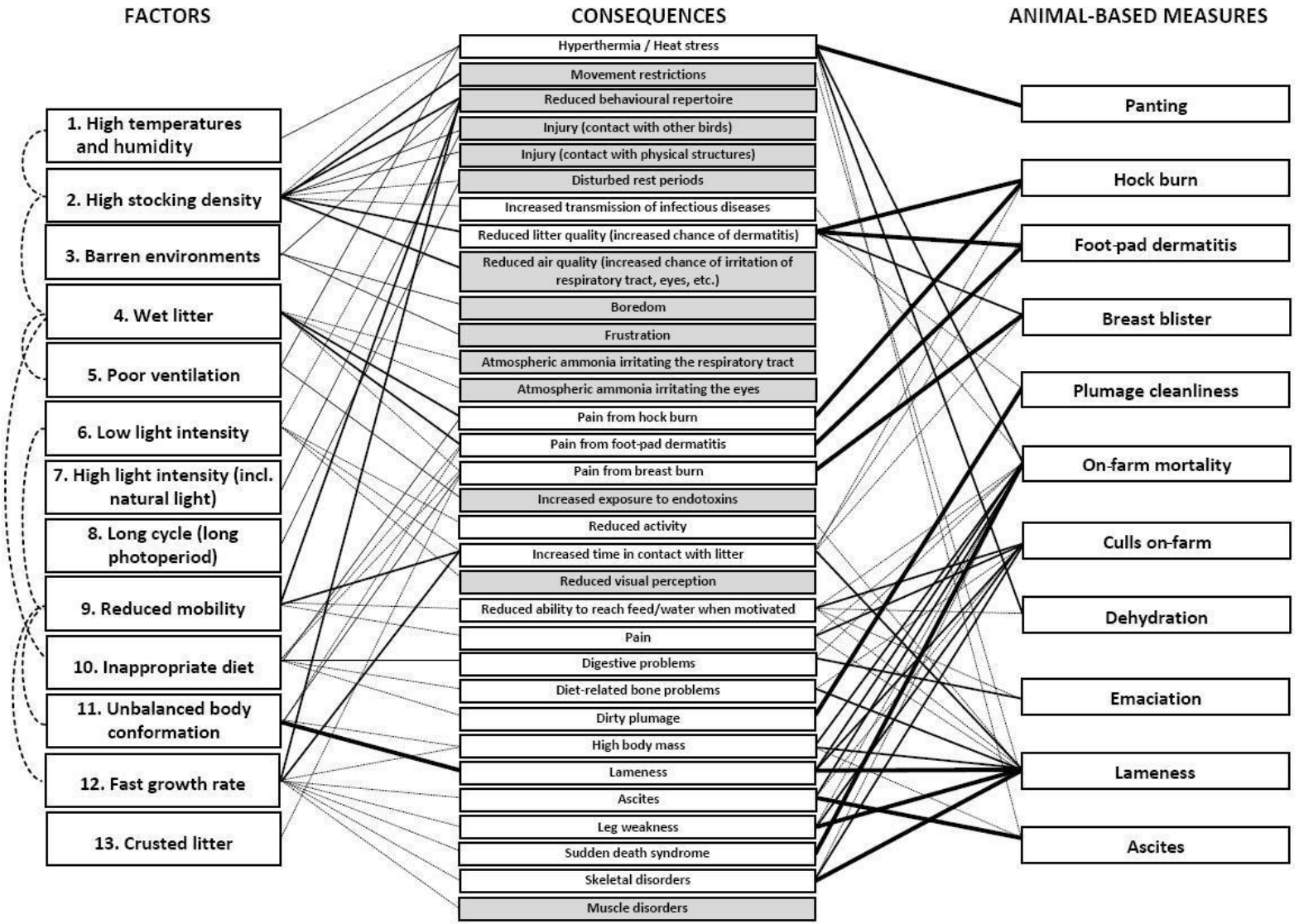


The width of the lines between animal-based measures and consequences provides a qualitative indication (given on a scale of 1-4; 4 (▬), 3 (▬), 2 (---), 1(—)) of the degree to which these associations are specific. Specificity is defined as the degree with which the animal-based measure is related to a single welfare consequence or whether it relates (responds) to several

different consequences. In this Figure only specificities ≥ 1 are shown (see Appendix B for the complete scoring results), and grey boxes are those that are not covered by an animal-based measure with adequate specificity (score < 1).

The width of the lines between factors and consequences provides a semi-quantitative indication of the probability *(P)* (either $P \geq 60\%$ (━), $60\% > P \geq 40\%$ (━), $< 40\% > P \geq 20\%$ (─), and $P < 20\%$ (---)) with which a consequence occurs given the presence of the factor (as calculated in risk assessment for previous broiler mandate; EFSA 2010a).
Broken curved lines indicate an unquantified relationship is proposed to exist between two factors.

Figure 2: Diagram highlighting associations between Factors and Consequences (focusing on risk), and between Consequences and Animal-Based Measures (focusing on sensitivity), in broiler welfare.



The width of the lines between animal-based measures and consequences provides a qualitative indication (given on a scale of 2-4; 4 (▬), 3 (▬), 2 (---)) of the degree to which these associations are sensitive. Sensitivity is defined as the probability that the consequence is detected by the animal-based measure (i.e. probability of a correct positive test). A score of 0, or a low score, implies no or little sensitivity and a poor chance that the animal-based measure will detect the consequence if it is there, whereas a high score implies there is good chance of detecting it. In this Figure only sensitivities ≥ 2 are reported (see Appendix C for the complete scoring results), and grey boxes outlined are those that are not covered by an animal-based measure with adequate sensitivity (score < 2).

The width of the lines between factors and consequences provides a semi-quantitative indication (either ≥60% (▬), ≥40% but <60% (▬), ≥ 20% but < 40% (─) and <20% (---)) of the probability (*P*) with which a consequence occurs given the presence of the factor (as calculated in risk assessment for previous broiler mandate; EFSA 2010a).
Broken curved lines indicate an unquantified relationship is proposed to exist between two factors.

ToR 2 also asks the question in the reverse direction to that presented so far, that is to say it asks the extent to which the main factors identified in the EFSA opinions are linked to the animal-based measures in the Welfare Quality® protocol. This is best illustrated in Table 2 (specificity scores) and Table 3 (sensitivity scores). In these tables the animal-based measures in the Welfare Quality® protocol are given in the rows and the number of consequences given in the columns. The number of consequences is listed separately according to the level of specificity or sensitivity (scores) so that it is possible to say not only how many Welfare Quality® animal-based measures are linked to a particular consequence, but also how many at each level of sensitivity/specificity.

There are two main aspects that are clearest when looking at these tables (Table 2 and 3). The first is that there are three Welfare Quality® measures ("huddling", "hepatitis" and "avoidance distance test") that do not address any consequence. Although it should be remembered that the focus here has been on main factors and their consequences. The other is that there are two Welfare Quality® measures ("on-farm mortality" and "culls on-farm") that measure a very high number of consequences although at relatively low levels of sensitivity and specificity. There are relatively few Welfare Quality® animal-based measures that measure consequences with high levels of both sensitivity and specificity (level 4 for both) and these are "plumage cleanliness", "panting", "lameness", "foot-pad dermatitis", "hock burn", "breast blister" and "ascites".

Table 2: Number of consequences measured by Welfare Quality® protocol animal-based measures with different scores for specificity (from 0 to 4).

Animal-based measure	Specificity				
	4	**3**	**2**	**1**	**0**
Emaciation	0	1	1	4	41
Plumage cleanliness	1	0	2	3	41
Panting	3	0	0	0	44
Huddling	0	0	0	0	47
Lameness	1	3	5	4	34
Hock burn	3	0	3	1	40
Foot-pad dermatitis	4	0	3	1	39
Breast blister	2	0	3	4	38
On-farm mortality	0	0	6	15	26
Culls on-farm	0	1	4	12	30
Ascites	1	0	0	5	41
Dehydration	0	1	3	0	43
Septicaemia	0	0	0	3	44
Hepatitis	0	0	0	0	47
Pericarditis	0	0	0	2	45
Abscess (sub-cutaneous pus)	0	0	0	3	44
Avoidance distance test (ADT)	0	0	0	0	47

Table 3: Number of consequences measured with Welfare Quality® protocol animal-based measures with different scores for sensitivity (from 0 to 4).

Animal-based measure	Sensitivity				
	4	**3**	**2**	**1**	**0**
Emaciation	0	1	1	4	41
Plumage cleanliness	1	0	2	3	41
Panting	3	0	0	0	44
Huddling	0	0	0	0	47
Lameness	3	4	6	0	34
Hock burn	3	0	3	1	40
Foot-pad dermatitis	4	0	3	1	39
Breast blister	3	2	3	1	38
On-farm mortality	1	5	7	8	26
Culls on-farm	0	5	2	10	30
Ascites	1	0	2	3	41
Dehydration	0	2	2	0	43
Septicaemia	0	0	0	3	44
Hepatitis	0	0	0	0	47
Pericarditis	0	0	0	2	45
Abscess (sub-cutaneous pus)	0	0	0	3	44
Avoidance distance test (ADT)	0	0	0	0	47

As stated in section 1.1.1, new factors were identified in the preparatory work (De Jong et al., 2012). These are listed in Table 4. The consequences linked with these are also listed. "Fear" is a consequence that was not identified in the EFSA (2010a) report although it was already identified in the SCAHAW (2000) report. The quality of the human-animal relationship, and stockmanship in general, was mentioned in the EFSA scientific report. The reason "fear" was not identified as a consequence is probably the lack of information on how best to assess it; instead "fear" was one of the welfare traits for which it was suggested that more studies were needed. Pain and distress due to inappropriate culling were also not mentioned in the EFSA (2010a) scientific report because it had no direct relationship with broiler genetics. Finally, cold stress was not identified in the previous EFSA (2010a) report as a consequence probably because it is not very common in practice.

Table 4: Factors additional to those described in the previous EFSA report (2010a) and the consequences as defined in the preparatory work (De Jong et al., 2012).

Additional Factor (Hazard)	Consequence (Adverse effect)
Lack of appropriate training for stockpersons and animal handlers - poor stockmanship	Fear
Use of inappropriate culling methods	Pain, distress
Inappropriate incubation process and poor hatchery hygiene	Ascites Lameness Heat stress
Low ambient temperature	Ascites, mortality, cold stress
Inappropriate type and quality of water equipment	Foot-pad dermatitis, hock-burn and breast burn through wet litter; Dehydration due to difficulty in accessing water
Overly dry litter	Respiratory diseases
Inappropriate enrichment	Boredom, frustration, injuries

2.2.3. Discussion

The Welfare Quality® project identifies, whenever possible, an animal-based measure in its protocol. This measure is very clearly linked to the 12 Welfare Quality® criteria (see section 1.1.2), but as can be seen from Figures 1 and 2, they are not always as clearly linked to a consequence presented in the EFSA scientific opinion (EFSA, 2010a). On the other hand, the EFSA opinion is very transparent in identifying factors and their consequences, but does not give comprehensive information about which animal-based measures should be used to describe these consequences in practice. This problem in linking Welfare Quality® protocols to EFSA factors is made difficult by the fact that an EFSA identified factor may lead to several consequences and a measure in the Welfare Quality® protocol could have several underlying causal factors. It is because of these multiple associations, that the specificity links seen in Figure 1 are often weak.

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 did not require a trained veterinarian or ethologist to be able to record them. The aim was that any person with good animal knowledge could perform them reliably after training. The consequences in the EFSA scientific opinion are often expressed in terms of a veterinary diagnosis or experimental studies. On the other hand, if the broiler is suffering from any of the disorders specified in the EFSA scientific opinion, then the Welfare Quality® protocol will, with all probability, detect this under the criteria "absence of disease" or through a general factor such as increased mortality.

Furthermore, the Welfare Quality® protocol was designed to be carried out on-farm within 1 day, which means that, when appropriate, a resource-based measure is used instead of an animal-based measure. An example of this is the use of the resource-based measure "stocking density" which is used

on the Welfare Quality® protocol as a reliable proxy for several of the consequences noted in the EFSA scientific opinion that would otherwise be time-consuming to record.

Another issue arising from addressing this ToR is that, according to the Welfare Quality® assessment protocol for poultry (Welfare Quality®, 2009), mortality and culls in broilers are regarded as management-based measures. Management-based measures are defined as measures which refer to what the animal unit manager does on the animal unit and what management processes are used (Welfare Quality®, 2009). An animal-based measure was defined as a measure that is taken directly from the animal (Welfare Quality®, 2009), a definition that is valid for mortality and probably also for culls given that mortality and culls are directly related to the status of the animal itself. Therefore, in this report we consider mortality and culling as animal-based measures. They are generally recorded on a flock basis.

In the remaining part of this section we discuss some of the issues that arose from the investigation when there was a consequence in the EFSA scientific opinion for which there was no animal-based measure in the Welfare Quality® protocol or where there was a lack of clarity in whether or not there was a measure in the Welfare Quality® report for which no consequence had been described in the EFSA scientific opinion. These refer mainly to the consequences "breast lesions", "lameness", "boredom" and "frustration", and to the animal-based measures "huddling", "hepatitis" and the "avoidance distance test" (touch test).

Two types of breast lesions in broilers have been described in the literature: breast burn and breast blister. "Breast burn" is a contact dermatitis characterised by a discoloration of the skin (brown to black appearance) and is similar to hock burn and foot-pad dermatitis (Greene et al., 1985). The main cause of this lesion is prolonged contact with wet litter, and it is the most common finding in broiler chickens. "Breast blisters" are infrequent and are characterized by an accumulation of fluid between the skin and the muscle (McCune and Dellmann, 1968). It is induced by pressure on the ventral aspect of the sternum or breast muscle or by infection with organisms such as *Escherichia coli*. In the Welfare Quality® protocol the description of breast blisters and the images for scoring are not very clear and will be improved in the revision of the protocol.

Birds with inflammatory disease are likely to experience pain and may show sign of lameness. McGeown et al. (1999) reported that lame broilers responded to treatment with an analgesic but they did not conduct a pathological investigation of the underlying cause of the lameness. Broiler chickens that are unable to walk or that move with difficulty (i.e. with gait scores 4 and 5) are unable to feed properly and are generally culled regardless of any considerations of pain. Extensive recent research on broilers with gait score 3 (i.e. those with an "awkward" gait) has shown that they do not respond to an analgesic, suggesting that they may not be experiencing pain, or that it is masked by other factors affecting walking (such as conformation; V. Sandilands, Scottish Agricultural College, personal communication, 2012). The lack of evidence for pain in broilers with gait score 3 is consistent with the finding that the gait of modern broilers is linked to their morphology (wide bodies and short legs; Corr et al., 2003). The gait score 3, even when not associated with pain, is still an indicator of poor welfare as the bird is less well able to compete for or move to resources when it wishes to do so.

Boredom and frustration are commonly ascribed to standard broiler chickens housed in conventional buildings and a case is made for environmental enrichment with items such as windows, perches, straw bales and "toys" (e.g. items which the birds can peck). There is little research into whether broiler chickens experience boredom or frustration; however some research was done with broiler breeders (Savory et al., 1992, 1993).

Huddling is a natural behaviour that birds show when they are cold. Thus huddling is an animal-based measure to assess the consequence cold stress and it is one of the measures in the Welfare Quality® protocol as persistent huddling is an indicator that the thermal environment is not being correctly maintained. It is stated in the protocol (Welfare Quality®, 2009) that it is less common than panting (an

animal-based measure of heat stress) and it is probably for this reason that huddling was not considered in the EFSA scientific opinion.

Hepatitis was one of the measures included in the Welfare Quality® protocol because it can be easily collected from slaughterhouse rejection data. It is not thought to be a major problem on-farm. On the other hand fear of humans is considered a welfare issue. This is addressed in the Welfare Quality® protocol by the use of the avoidance distance test (touch test). The quality of the human-animal relationship, and stockmanhip in general, was mentioned in the EFSA scientific report. (EFSA, 2010a). The reason it is not identified as a consequence is probably the lack of information on how best to assess it and fear was one of the welfare traits for which it was suggested that more studies were needed.

Research quantifying the sensitivity and specificity of animal-based measures would address the complex links between factors, consequences and animal-based measures. This is necessary in order to select the optimal set of animal-based measures to accomplish the specific purpose of the assessment. For example if the aim is to identify flocks that are at of risk of welfare problems, animal-based measures with high sensitivity should be chosen. If the aim is to develop management strategies, animal-based measures with high specificity should be chosen so that the relevant causal factor can be identified.

In this scientific opinion qualitative descriptions of sensitivity and specificity are used. In the future quantitative descriptions of sensitivity and specificity of animal-based measures should be developed. This requires a database containing causal factors and animal-based measures and will ultimately support selection of the optimal set of animal-based measures for different purposes.

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

2.3.1. Procedures to address this question

To address ToR 3, the tables developed for ToR 1 (how animal-based measures can be used to fulfil recommendations, see Table 1 and Appendix A) and ToR 2 (linking the Welfare Quality® assessment protocol and factors, see Figures 1 and 2 and Appendices B and C) were studied. The focus was on identifying factors for which there were no corresponding animal-based outcome measures or for which the available animal-based measures did not adequately link poor welfare to the causal factor. That is to say, even if there was a measure it had low specificity and low sensitivity.

2.3.2. Main findings and issues

Seven consequences from the list in Appendices B and C were found for which there was no animal-based measure in the Welfare Quality® broiler protocol. These were:

- “reduced behavioural repertoire” linked to the 4 factors - “high stocking density”, “barren environments”, “low light intensity”, “reduced mobility;
- “disturbed rest period” linked to the factors “high stocking density” and “light cycle (long photoperiod)”;
- “reduced air quality” linked to the factor “high stocking density”;
- “frustration” linked to the factor “barren environments”;

- "boredom" linked to the factor "barren environments"[9];
- "atmospheric ammonia irritating the eyes" linked to the factor "wet litter";
- and "reduced visual ability of the bird" linked to the factor "low light intensity".

In other cases, consequences are linked to only one animal-based measure. For example, in the case of "sudden death syndrome", which is linked to the factor "fast growth rate", the only animal-based measure is "on-farm mortality", and it is very sensitive (score 4) but not very specific (score 2). Its importance is therefore low, which means that this animal welfare issue cannot be assessed properly using that animal-based measure.

There are also consequences for which there is only one animal-based measure but with a high sensitivity and specificity (score 4). These animal-based measures would probably be appropriate in assessment protocols. For example in the case of the consequence "pain from foot-pad dermatitis", which is linked to the factors "wet litter" and "unbalanced body conformation"; the only animal-based measure is "foot-pad dermatitis" and it is very sensitive and very specific (score 4 for both).

There is a limited number of animal-based measures for the consequence but their relevance was low. For example, for the consequence "muscle disorders", which is linked to the factor "fast growth rate", there were two animal-based measures ("on-farm mortality" and "culls on-farm") with very low sensitivity (score 1) and no specificity (score 0).

2.3.3. Discussion

The relative merits of the use of animal-based measures and resource-based measures require some discussion. It is likely that a simple scoring system in which an individual is scored as with or without signs of irritation of the eyes could be developed as a useful measure (Butterworth and Niebuhr, 2009). For example, the measure of the number of broilers with or without eye discharges and swollen eyes has been used during the Welfare Quality® project (Arnould and Colin, 2009; Arnould and Butterworth, 2010) and is in the protocol developed for laying hens (Welfare Quality®, 2009). However in practice, is it easier, and less stressful to the birds, to record the level of ammonia and air quality rather than to select and score a sample of broilers? It should be mentioned that level of ammonia can vary greatly from day to day depending on the litter replacement and where the measure is performed (higher levels in areas with low ventilation, such as in the corners of houses). Litter quality is very closely correlated with air quality and this is in the Welfare Quality® broiler protocol under the criterion "comfort around resting" (Al-Homidan et al., 2003, Welfare Quality®, 2009; Baeza et al., 2012). It is also considerably easier to measure light intensity than to carry out behavioural observations of the perception ability of birds. However, there is no measure of light intensity in the Welfare Quality® protocol because it appears that during the testing of the prototype of the protocol that the measurement could not give a good indication of the light intensity inside the building.

Muscle disorders are associated with genetic selection for high growth rate. Deep pectoral myopathy could sometimes be a current problem in fast-growing broilers as Dinev and Kanakov (2011) reported an incidence of 0.51% in intensively reared Bulgarian flocks. The condition is undoubtedly painful for affected birds but it can only be detected post mortem. Myopathies are important meat quality defects and are highly likely to be noted if they were present in commercial flocks to any great extent. Generalised muscle pathology has been described in broiler chickens and may be detected using a blood test for the activity of creatine kinase (MacRae et al., 2006, 2007; Sandercock et al., 2009). The consequences for the welfare of broilers have not been thoroughly investigated but must be negative.

A further consequence for which no animal-based measure has been used for broilers is "frustration". It is linked to the factor "barren environment". Severe frustration in birds has mainly been studied in

[9] "Frustration" and "boredom" were part of QBA.

laying hens and in feed restricted breeders. Severe frustration typically results in stereotyped pacing and increased aggression whereas mild frustration results in displacement preening. Motivation and frustration of highly motivated behaviours is an important part of the welfare of an animal. Bokkers et al. (2007) found that the physical abilities of broilers are likely to reduce their ability to behave in accordance with their motivation, for example, to show stereoptyped pacing.
Using automated sampling from sensors, and *a priori* knowledge of the undisturbed pattern in broilers, may increase the probability that lying and movement patterns could be used to detect this problem. However, knowledge of the normal range which encompasses individual variability is necessary to detect states that indicate adverse consequences. Frustration may in many cases result only in physiological stress responses that are difficult to measure in a simple way, and therefore not possible to use as a simple and valid animal-based measure.

The factor "barren environment" has two other consequences linked to it. These are "reduced behavioural repertoire" and "boredom". Moreover, there are not currently good animal-based measures to detect these two consequences. As mentioned above, video imaging techniques could be used to detect evidence of a reduced behavioural repertoire and work is in progress to use pattern recognition in poultry barns to detect deviations from normal (Aydin et al., 2010); however, such techniques are not yet practical for the average broiler farmer. There are no resource-based measures of barrenness of environment currently in use, although Welfare Quality® includes as a measure the availability or otherwise of free-range access, as an indication of environmental enrichment.

A reduction in capacity to perform normal behaviour can also be caused by "high stocking density" and this is the factor for the consequence "disturbed rest periods", which is not covered by any animal-based measures. However, there is general agreement that there is an increase of disturbances at higher stocking densities (Hall, 2001; Cornetto et al., 2002; Dawkins et al., 2004; Febrer et al., 2006; Buijs et al., 2010; Ventura et al., 2012) which fragment preening and resting bouts (Hall, 2001; Buijs et al., 2010, 2011). Likewise, walking bouts were found to be shorter at higher stocking densities (Hall, 2001; Febrer et al., 2006; Buijs et al., 2010), with birds covering less distance per unit of time (Leone and Estevez, 2008a, b), suggesting that it becomes increasingly difficult to move around as density increases. Spindler and Hartung (2011) showed at a density of 42 kg/m^2, broilers have less space per bird for movement and behavioural activities, such as wing stretching or preening than laying hens in enriched cages. The Welfare Quality® broiler protocol includes the measure "stocking density" in its criteria to assess ease of movement rather than time-consuming behavioural observations. However, it should be possible to develop a standardized behavioural observation method for a short time recording the number of disturbances per unit of time, as done for experimental studies.

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

2.4.1. Procedures to address this question

The information compiled in the previous EFSA Scientific Opinions on the welfare of broilers and the Welfare Quality® project provided some indications as to which factors can be controlled through management. In this scientific opinion, a Delphi approach (Rowe and Wright, 1999; Yousuf, 2007) was used. The Delphi approach consists of three steps: i) selection of relevant questions to be asked; ii) individual scoring of these questions by experts, with the option of changing the initial scores after being provided with the scores of the other experts; and iii) consensus discussion.

For the purposes of this ToR, 13 factors and 47 factor characterisations (welfare consequences) identified in the risk assessment in the Scientific Opinion on the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers (EFSA, 2010a) were considered to be the main factors in the husbandry system which have been scientifically proven to have negative effects on the welfare of broilers.

Taking into consideration the short production cycles for broilers, the possibility of management control for factors affecting welfare between flocks and within flock were considered separately. Therefore, for each of the 13 factors, questions were formulated on:

- control potential through management between flocks
- control potential through management within flock

With respect to welfare consequences, the possibility of management control only within flocks was considered. Therefore, for each of the 47 welfare consequences, questions were formulated on consequence control potential through management.

In the second step, the list of factors with categorisation, respective risk estimates and magnitude of consequences was sent to all members of the Working Group (n=7). They were asked to express, independently for each factor, their opinion whether the risk of this factor could be prevented by management between flocks and/or within flock. A scoring system ranging from 1 (very poor potential to control or mitigate the factor through management) to 5 (very good potential to control or mitigate factor through management) was used. Responses were pooled and summarised by calculating the mean and median, as well as the minimum and maximum scores for each factor. Since it was identified quickly that for some factors the full range of options was scored, some time was spent in the Working Group discussing issues of clarification. The same scoring system was used to quantify the potential to control each for the 47 welfare consequences by management within flock.

Whenever necessary, the experts discussed as a group, how to handle any obscurities or ambiguities. These were mainly related to the distinction between factors, their consequences and the animal-based measures. In some cases a factor (such as "wet litter" or "reduced mobility") was also an outcome that could be measured, in this case "litter quality" (resource- and management-based measure) and foot-pad dermatitis (animal-based measure) respectively.

It should be acknowledged that the vast majority of commercially reared broilers in the EU member states are reared under relatively standardized conditions, compared with other farm animal species. Usually, confined animal houses are used where the birds are kept on the floor covered with litter such as straw, wood shavings or similar moisture-absorbing materials. The buildings are typically unstructured but equipped with feed and water delivery lines which can be easily reached by the birds under normal conditions. The buildings are mechanically ventilated or fresh air is supplied by natural ventilation through open curtains along the sides of the buildings. Biosecurity of broiler flocks is managed by an all-in-all-out policy. The lists of factors and consequences are based on what can occur in such systems.

2.4.2. Results of the Delphi exercise

Mean, median, minimum and maximum for the scores reflecting possibility of management control of 13 factors between flocks and within flock are presented in Table 5 (see also Appendix E)

Mean, median, minimum and maximum for the scores reflecting possibility management control of 47 welfare consequences within flock are presented in Appendix F.

Table 5: Possibility management control of factors between flocks and within flock

	Factors description	FACTORS control potential through short term management BETWEEN FLOCKS				FACTORS control potential through short term management WITHIN FLOCK			
		Mean	Min	Max	Median	Mean	Min	Max	Median
1	High temperatures and humidity	4.33	4	5	4.0	3.67	3	4	4.0
2	High stocking density	4.50	3	5	5.0	1.67	1	3	1.5
3	Barren environments	4.17	3	5	4.0	3.33	2	4	3.5
4	Wet litter	4.17	3	5	4.0	2.50	1	4	3.0
5	Poor ventilation	4.33	4	5	4.0	3.17	2	5	3.0
6	Low light intensity	4.83	4	5	5.0	4.17	3	5	4.0
7	High light intensity (incl. Natural lighting)	4.33	3	5	4.5	3.17	2	4	3.0
8	Light cycle (long photoperiod)	4.83	4	5	5.0	4.50	4	5	4.5
9	Reduced mobility	2.33	1	3	2.5	1.33	0	3	1.0
10	Inappropriate diet	4.83	4	5	5.0	2.67	1	4	2.5
11	Unbalanced body conformation	3.17	2	4	3.0	0.67	0	1	1.0
12	Fast growth rate	3.17	1	4	3.5	2.00	1	4	2.0
13	Crusted litter	4.50	3	5	5.0	3.00	2	4	3.0

2.4.3. Discussion

From Appendix E and Table 5, it is clear that all factors except "reduced mobility", "unbalanced body conformation" and "fast growth rate" can be controlled through management between flocks (median score ≥ 4). In contrast, within flock management can control only "high temperature and humidity", "low light intensity" and "light cycle" are manageable (median score ≥ 4).

From Appendix F, it is clear that only a few welfare consequences can be controlled efficiently through management within flock, specifically "hyperthermia/heat stress", "reduced litter quality" and "reduced air quality" (median score ≥ 4). It is interesting to note that "reduced litter quality" and "reduced air quality" are consequences with high welfare impact; therefore, their control through management could be very beneficial. On the other hand, "reduced behavioural repertoire" and "reduced activity" are consequences with high welfare impact but with very low or low potential to be

controlled through within flock management. In the case of these consequences, between flock management control of the causal factors ("fast growth rate", "low light intensity" and "stocking density") is likely to be more effective. Such management control might include modification of feeding and lighting schemes

In this opinion, biosecurity and flock health management have not been specifically addressed, because they had not been indentified in the risk assessment of the previous EFSA scientific opinion (EFSA, 2010a). In broiler production the exposure to microbial and parasitic pathogens can easily result in various infections and infestations, which can lead to diseases of varying severity and associated welfare consequences. These consequences can largely be prevented by the implementation of biosecurity measures and by flock health management. Poor biosecurity and poor health management (including the use of antibiotics; DANMAP, 2010) should therefore be considerer as additional to those major factors listed in Table 5.

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

This opinion shows that there are complex associations between factors, consequences and animal-based measures, something that was also recognised during work on the first scientific opinion in this series on the use of animal-based measures to assess the welfare of dairy cows (EFSA, 2012b). To address this, a review of methodologies was commissioned during that dairy cattle work as well as a follow-up study to test the proposed methodology. A brief summary of the main findings is given below.

Way of dealing with this complexity that have been developed since the publication of the scientific opinions on the use of animal-based measures to assess the welfare of dairy cattle (EFSA, 2012b) and pigs (EFSA, 2012c) are summarised later in this section. To avoid repetition of the EFSA statement on the use of animal-based measures (EFSA, 2012d), which outlines some of these issues, the emphasis here is on broiler welfare and on developments that are unique to this scientific opinion.

3.1. Summary of findings from a review of methodologies and from pilot projects to investigate the relationship between animal welfare factors and animal-based measures

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

A follow-up study (Brenninkmeyer et al., 2012) applied these methods to selected animal-based measures using dairy cattle data as an example (integument alterations and locomotion disorders) as output variables. The main goal was to correctly classify farms at risk. The study showed that the methodologies are suited to the analysis of the complex relationships between animal-based measures and factors to enable identification of farms at risk of poor welfare and identified the value of classification tree models for additional analyses. For successful implementation of these analyses, user friendly database management systems that can store data in a standardised way are required to facilitate the development of improved models based on the best scientific evidence.

3.2. Development of tools to monitor broiler welfare

In animal health research, the visualisation of links between factors and health indicators is based on harmonised collection of standardised indicators followed by analyses to investigate relevant associations. At present, this can be done only on small sets of data collected for animal welfare purposes, as in the example above. However, if some of the animal-based measures of broiler welfare suggested in this scientific opinion were to be collected in a systematic way, then this would pave the way to investigate not only the associations among factors, consequences and animal-based measures, but also the predictive capacity of the correlations or associations. When populated and used appropriately, this database approach could assist in selecting the most effective animal-based measures from the "toolbox", and would ultimately provide the type of information required for quantitative risk assessment of animal welfare. At present the lack of such data means that associations and estimates of the strengths of these associations are based on expert opinion.

The development of tools to monitor animal welfare needs to take into consideration not only what is to be recorded, and how the data will be analysed to generate new knowledge that can be used in risk assessment, but also the implications of the results gathered on-farm. If it is foreseen that actions will be taken when predefined threshold levels are exceeded, then one it is typically talking about surveillance rather than of monitoring. It may even be that the welfare status is monitored again, after the intervention, to determine whether or not there has been any improvement in welfare. Such a "before versus after" assessment would be necessary for economic analyses, for example when comparing the cost effectiveness of different interventions against the gains in welfare post-intervention. Such information is useful at the level of the farm, when making management decisions, but it would also be useful information at the country and EU level, when companies or governments are making policy decisions. The systematic recording of standardised animal-based measures from the validated measures in the toolbox then becomes part of an animal welfare surveillance scheme. Benchmarking of animal-based measures on a large scale might 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 sector e.g. changes in breeding goals, changes in raw ingredients in feed etc. Benchmarking of important animal-based measures on a large scale would allow quicker feedback to policy makers on the effectiveness of legislation or other initiatives to improve animal welfare.

Council Directive 2007/43/EC, laying down minimum rules for the protection of chickens kept for meat production requires that if broilers are to be kept at stocking densities greater than 33kg/m^2 then information on animal-based measures (daily mortality rates and the cumulative mortality rate) should be monitored for each flock. These data are from a non-representative sample of flocks (only those with high stocking density), and mortality rate has poor specificity and sensitivity as an animal-based measure (Figures 1 and 2). However, "on-farm mortality" is associated with a high number of consequences (Tables 2 and 3) and it is still valuable providing that it could be compiled into one or more accessible databases so that the appropriate information can be extracted. For example, information on the causes of mortality (including causes for culling) is of importance to extract appropriate information. Furthermore, if information on the farms being monitored (e.g. housing system) or even more detailed information on relevant input factors (such as those described in the directive that are to be documented by the farmer) the potential to quantify links between factors and a single animal-based measure (mortality) becomes feasible on a much larger sample than before. Article 3 (5) of the Directive foresees that a stocking density up to 42kg/m^2 may be allowed when, in at least seven consequently checked flocks from a house, the cumulative daily mortality rate was below 1% plus 0.06% multiplied by the slaughter age of the flock in days (1 + (0.06 x age in days) %), setting therefore a threshold for such measure. Analysis of the factors affecting mortality would allow a quantitative risk assessment of a change in any of the factors on mortality. Thus, although this approach is a clear move in the direction of harmonised data collection of standardised animal-based measures in the field, it refers to only one animal-based measure and how the data is to be made available, especially in relation to the relevant factors on the farm, is unclear.

Whereas 14 of the Directive says that *"It is appropriate for the Commission to submit a report based on new scientific evidence taking into account further research and practical experience... .. That report should specifically consider the possibility to introduce thresholds for indications of poor welfare conditions identified during the post mortem inspections and the influence of genetic parameters on identified deficiencies resulting in poor welfare of chickens kept for meat production."* Article 6 (2) foresees that *"Member States shall submit to the Commission the results of data collection based on the monitoring of a representative sample of flocks slaughtered during a minimum of one year"*. It is intended that the data collected for one year and analysed will be used to identify possible indications of poor welfare conditions. Within the frame of the ongoing work of the Commission on the modalities for collecting harmonised data on welfare indicators in broilers' slaughterhouse, seven animal-based measures (such as "hock burns", "foot-pad dermatitis", etc.) are being considered. These are among the animal-based measures listed earlier (section 2.1).

If such information is to be widely used, the animal-based measure has to be standardized. Measures have to be taken to ensure that the signs of disease or injury applied are the same throughout countries and regions. For this purpose instructions will have to be developed and distributed and people will need the appropriate training. It is not clear at present how standardised the data collection of welfare indicators at slaughterhouses is going to be.

Automation of data collection is a valuable tool for animal-based measurements in broilers and there are already several developments in this area. As broilers are generally housed in flocks of thousands of birds, manual data collection can often only be done on a sample of birds per flock and can be very time-consuming. In the case of data collection at slaughter, automation enables sampling of many more birds per flock. But automation may also be helpful on-farm, where changes e.g. in food and water consumption, body weight, activity and spatial distribution, at flock level may be detected by automated systems. Automated data collection may also be more efficient and objective compared with manual data collection. Examples of automated data collection at the slaughter plant are existing video imaging systems that score carcass quality attributes such as bruises and broken wings. A similar system has been developed for scoring foot-pad lesions in broiler chickens and has recently been introduced in two slaughter plants. A big advantage of such a system over visual inspection for scoring of feet for foot-pad dermatitis (details below) is that more than 75% of the broilers are scored, compared with the "standard" sample of 100 feet per flock when feet are scored manually (De Jong et al., 2008, 2011). Examples at flock level are systems that can be used to monitor deviations in activity levels in broiler flocks. Aydin et al. (2010) developed an automatic image monitoring system for broiler activity that potentially can be used to assess gait score. Kristensen and Cornou (2011) have developed a digital motion detection system to detect abnormal deviations in activity level. Both systems have been developed under experimental conditions and should be tested at field level.

This scientific opinion shows that there are typical animal-based measures which can be recognised on-farm such as "panting", "dehydration", "lameness", "culls on-farm", "on-farm mortality", "plumage cleanliness" and "extreme forms of emaciation". However, not all useful animal-based measures can be observed and quantified under normal farming conditions, particularly at the end of the production cycle, when animal density is approaching its limit. The next opportunities to record animal measures are when loading for transport, unloading at the slaughterhouse and after defeathering and the "scalding tank" in the slaughter line, when the carcasses undergo a final visual meat inspection check by veterinarians or other trained inspectors. Rough figures from practice indicate that at this point, between 1% and 2% of the slaughtered birds are discarded because of deficiencies such as bone breakages that perforate the skin, heavy bruising, emaciated bodies, or signs of infection in lungs or other organs (Ulrich Löhren, personal communication, 2012). In Germany alone 1%, which would amount to approximately 9,700 tonnes per year of broiler meat, is removed from the food chain because of hygiene and disease concerns, when the production figures from 2011 are taken (609,015,898 broilers of 1.6 kg; DSTATIS, online).

Moreover, this visual inspection is an ideal point where animal-based measures can be taken. This would give qualitative and quantitative results. In particular, indicators (animal-based measures) such

as "foot-pad dermatitis", "hock burn", "breast blisters" and also "emaciation", "ascites" and "dehydration" can be visually detected and recorded, even at slaughter line speeds.

A system of routine recording of foot-pad dermatitis in broilers was developed in the mid-1990s in Sweden, and was later adopted in Denmark, and is now applied at all broiler slaughterhouses in these countries. The system, which has been thoroughly described in the scientific literature (Ekstrand et al., 1998; Algers and Berg, 2001; Berg and Algers, 2004), is based on the visual examination of a systematic random sample of 100 single broiler feet per flock at slaughter. The feet are examined after scalding, and given a score from 0 (no lesions), to 1 (mild, superficial lesions, discolouration) or 2 (severe lesions, ulcers). These scores are then weighted and summarised to give a total flock score, which is used as a direct indicator of foot-pad dermatitis and an indirect indicator of litter quality and bird management. The system has proven relatively easy to enforce and standardize using short courses and photographic material. The benchmarking of this over time has resulted in the prevalence of foot-pad dermatitis decreasing (Berg and Algers, 2004) and if increases have been recorded it has facilitated the identification of the causal factor (Berg and Algers, 2004). The results are reported back to farmers and involved organizations and show where urgent actions have to be taken, either immediately before the next fattening flock arrives on the farm (e.g. new and better absorbing litter) or by introducing more fundamental changes in the animal houses (e.g. equipment, enrichment).

A similar scoring system using a five-point scale (which could easily be simplified to a three-point scale) with clear visual description of the lesions associated and histologically validated has recently been proposed (Michel et al., in press).

Thus, it is recommended that visual inspection at the slaughter line be used to monitor animal-based measures as a practical and effective tool in order to improve animal welfare in broiler production. The similarities between the complex associations related to factors and animal-based measures for monitoring welfare and the association between factors and indicators of disease have been mentioned previously. Thus, it is logical when considering the development of tools to monitor broiler welfare to consider the developments that have been used in health monitoring. In general this system is made up of the following steps: first, identification of the goal; second, identification of the population concerned and definition and selection of the survey population; and the third step is the selection of the animal-based measures from the toolbox and the systematic collection of data. Following the analyses of the data, the results are interpreted. This analysis and interpretation may in practice be done automatically as part of a management software programme or on the website of the appropriate animal industry. In some cases a recommendation for action is developed and implemented. The goal and the survey population are reappraised and when necessary adapted and then more data collected on the same measure(s) to verify whether the action has resulted in the intended effect.

This is effectively what has already happened in several countries that have targeted the improvement of litter quality in barns using the animal-based measure of foot-pad dermatitis. The project within the member states on data collection at slaughterhouses is also another example of this. In both cases the choice of animal-based measures was made first. However, if information from these projects is made available it may be possible to start to investigate the links between different animal-based measures.

The work in this opinion has identified some animal-based measures that are not included in the above data collection and depending on the experiences from the broiler slaughterhouse project it will be important to consider additional animal-based measures. According to the work in this scientific opinion the strongest animal-based measures that can be recognised on-farm are "panting", "dehydration", "lameness", "culls on-farm", "on-farm mortality", "plumage cleanliness" and "emaciation". The animal-based measures which can be comprehensively recognised at the slaughterhouse during meat inspection are: "foot-pad dermatitis", "hock burn", "breast burns", "breast blisters", "emaciation", "ascites" and "dehydration".

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

TOR 1:

1. There is a wide range of animal-based measures to ensure fulfilment of EFSA recommendations.

2. In order to obtain information about the welfare of the birds in a flock, using animal-based measures, it is necessary to select a sufficient number of birds and samples that are representative for the purpose of the assessment. On-farm assessment has to be conducted at an appropriate time.

3. Among on-farm measures, some are already routinely applied (e.g. "mortality", "growth rate", "water consumption"), and some are not yet used in commercial practice (e.g. "gait score", "plumage cleanliness").

4. Visual inspection at slaughterhouse, as currently practiced, can use animal-based measures to reflect welfare on-farm (e.g. "emaciation", "foot-pad dermatitis", "hock-burn", "breast blisters", "ascites"). Changes in these practices may result in the loss of this information.

5. Validity in relation to animal welfare, repeatability and reliability of these animal-based measures has not been fully established.

6. There is a high potential for automatic recording of several of these animal-based measures. Automatic recording of weight gain is already common practice; video imaging of foot-pad dermatitis at slaughterhouses is increasingly used commercially; automatic monitoring of e.g. flock activity is under development.

7. Systematic recording of animal-based measures that assess the welfare concerns identified in the EFSA scientific opinion (EFSA, 2010a) would provide a benchmark to monitor whether genetic changes in the breeding stock have been reflected in the welfare of broilers in commercial flocks.

TOR 2:

8. There are several consequences for which no animal-based measures were suggested by the Welfare Quality® protocol. These are for example: "reduced behavioural repertoire" and "injury". However, they could be covered by one of the non animal-based measures in the Welfare Quality® protocol, e.g. "stocking density".

9. There are three factors ("barren environments", "high light intensity" and "long light cycle/photoperiod") with many consequences that are neither associated with an animal-based measure, nor with a non-animal-based measure in the Welfare Quality® protocol.

10. There are three animal-based measures in the Welfare Quality® protocol that do not address any welfare consequence identified in the EFSA scientific opinion (EFSA, 2010a). These are: "huddling", "hepatitis" and "avoidance distance test (touch test)".

11. This opinion confirms that the factor-based approach and the consequence-based approach, as outlined in the guidance on risk assessment for animal welfare (EFSA, 2012a), are complementary.

12. The sensitivity and specificity of the majority of animal-based measures are low. Some are very sensitive but unspecific, e.g. "on-farm mortality", which does not provide information about

the cause of death. Although others are both highly sensitive and specific, such as "panting", which occurs as soon as, and only when birds are heat stressed.

TOR 3:

13. Animal-based measures can be used to assess most relevant welfare issues for broilers.

14. There are seven consequences of conditions and management ("reduced behavioural repertoire", "disturbed rest period", "reduced air quality", "frustration", "boredom", "atmospheric ammonia irritating the eyes" and "reduced visual ability of the bird") for which there was no animal-based measure in the Welfare Quality® broiler protocol. "Frustration" and "boredom" were however part of QBA.

15. There are consequences of conditions and management for which there are no animal-based measures in the Welfare Quality® protocol even though potential animal-based measures do exist. However, some of these potential animal-based measures are not feasible or not fully developed and validated, e.g. a measure of irritation of the eyes due to atmospheric ammonia. Other animal-based measures for some of the welfare issues related to emotional states in animals, such as QBA to assess boredom and avoidance distance test to assess fear, are not generally well understood and thus the validity of these measures is unclear.

16. Some very specific welfare issues can be technically assessed using non animal-based measures, therefore circumventing the lack of practical and feasible animal-based measures, e.g. levels of atmospheric ammonia is positively correlated with eyes irritations, and light intensity affects the visual ability of the broilers.

TOR 4:

17. There are many factors in husbandry systems which have been scientifically proven to have negative effects on the welfare of broilers. However, there is a large variation in the extent to which these factors can be managed to reduce their negative welfare consequences.

18. All factors identified in the EFSA scientific opinion (EFSA, 2010a) except "reduced mobility", "unbalanced body conformation" and "fast growth rate" can be controlled through management between flocks.

19. "High temperature and humidity", "low light intensity" and "light cycle factors" can be effectively controlled by management during the production cycle.

20. A few welfare consequences, in particular "hyperthermia/heat stress", "reduced litter quality" and "reduced air quality", can be controlled by management during the production cycle.

21. Among consequences responsive to management, foot-pad dermatitis, irritation of the respiratory tract and irritation of eyes as a result of "reduced litter quality" and "reduced air quality", have a high welfare impact, therefore, controlling them through appropriate management would be especially beneficial.

22. Some consequences of conditions and management can be managed, even if the original causal factors are present, whereas other consequences cannot be managed unless the original causal factor is modified. For example, "reduced activity" has a high welfare impact, but a low potential to be controlled, so a better strategy is to implement a between-flocks management control of its causal factors, "fast growth rate" and "low light intensity".

23. Optimizing biosecurity and health managements procedures have a great potential for minimizing health associated welfare consequences.

RECOMMENDATIONS

TOR 1:

1. As visual meat inspection is important to reflect welfare on-farm (e.g emaciation, foot-pad dermatitis, hock-burn, breast blisters, ascites.), a number of animal-based measures should be routinely used in the slaughterhouse.

2. Research to ensure validity, repeatability and reliability and other essential attributes of animal-based measures should be carried out.

3. Automatic recording of animal-based measures at the slaughterhouse and on-farm is promising and should be further developed, as this would improve feasibility and standardisation of measures.

TOR 2:

4. Research into quantifying the sensitivity and specificity of animal-based measures should be carried out in order to be able to address the complex links between factors, consequences and animal-based measures.

5. Both the factor-based approach and the consequence-based approach should be considered when developing strategies for the use of animal-based measures to assess the welfare of broilers.

6. Sensitivity and specificity should be always taken into account when selecting the appropriate animal-based measures, as requirements in these characteristics may vary according to the purpose of the assessment.

TOR 3:

7. Research is needed to understand emotional states in broilers in order to develop valid animal-based measures.

8. Research is needed to develop appropriate technology for the continuous and reliable monitoring of important environmental factors, such as levels of atmospheric ammonia, light intensity, air quality etc.

TOR 4:

9. Management programmes should be developed for those factors that have been shown to be responsive to management. More research is needed on alternative strategies to reduce the negative consequences of those factors that cannot be controlled by management.

10. Developing management programmes to improve litter and air quality should be given high priority.

11. For negative consequences not entirely solvable using management, strategies to modify the causal factors should be developed, e.g. growth rate (by selection and management factors) and avoidance of low light intensity to address reduced activity.

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APPENDICES

A. APPENDIX 1: RECOMMENDATIONS (EFSA, 2010A), CONSEQUENCES AND ANIMAL-BASED MEASURES – TOR 1

EFSA (2010a) section	Recommendations	Consequence	Available animal-based measures[§]	
			Welfare Quality® (2009)	From other sources
Overview of the welfare of broilers	1. Surveillance systems to collect relevant data on broiler welfare, including health, in Europe should be put in place to monitor trends in the prevalence and magnitude of poor welfare (i.e. degree of suffering) of leg problems, foot-pad dermatitis, ascites and sudden death syndrome in commercial flocks. This would also help to identify emerging problems.			
Mortality	2. Data on welfare outcome indicators such as mortality, found dead and culling rates should be recorded. In addition, the reasons for mortality and culling, the numbers of birds found dead, gait scoring and ascites in commercial rearing conditions should be recorded and made publicly available by breeding companies for each genetic line of broilers. This information could be used by farmers when selecting lines to purchase and by competent authorities checking on welfare.	Mortality[ç]	-Culls on-farm (F) -On-farm mortality (F)	-Found dead[ç] (F) -First week mortality[ç] (F) -Cumulative daily mortality rate: Council Directive 2007/43/EC (F) -Daily mortality rate[ç] (F)

Musculoskeletal disorders	3. Decreasing the proportion of birds with score 4 and 5 should receive a high priority and should be addressed through increased selection pressure on all factors contributing to high gait scores as well as through improved management.	Musculoskeletal disorders (infectious, developmental, degenerative) [ς]	-Gait score[ς] (F)	-Gait analysis: Reiter and Bessei, 1997; Stojcic and Bessei, 2009 (F) -Digital motion detections: Dawkins et al., 2009; Kristensen and Cornou, 2011 (F) -Anatomical and pathological changes: Butterworth and Arnould, 2009 (F/S) -Automated activity recording: Aydin et al., 2010 (F) -Latency to lie test (waterbath test): Weeks et al., 2002 (F), modified latency to lie test: Berg and Sanotra, 2003 (F) -Force plate assessment: Sandilands et al., 2011 (F), For review see Butterworth and Arnould, 2009
	4. Gait scoring should be carried out in a standardised way on all broiler production and breeding farms. If a significant proportion of birds have scores of 3 and above then this should trigger a review of systems of genetic selection, management or housing to be changed to improve the birds‟ welfare. Thresholds of concern should be established and depending on the threshold chosen, it is expected that the eradication of this welfare problem will take some years.	Musculoskeletal disorders (infectious, developmental, degenerative) [ς]	See measures for recommendation 3.	
	5. Birds that move with difficulty, or not at all, (gait scores 4 and 5) should be culled.	Musculoskeletal disorders (infectious, developmental, degenerative) [ς]	See measures for recommendation 2 and 3.	

	6. Breeding companies should be encouraged to identify traits suitable for selection that would improve gait scoring of birds in their commercial lines.	Musculoskeletal disorders (infectious, developmental, degenerative) [ς]	See measures for recommendation 3.	
Muscle disorders	No recommendations	Muscle disorders: myopathies (deep pectoral myopathy, muscular dystrophy) and muscle damage[ς]		-Biochemical indices of muscle damage[ς]: Sandercock et al., 2009; McRae et al., 2006; Dinev and Kanakov, 2011 (F/S) -Anatomical and pathological changes, autopsy: Gregory, 1998 (F/S)
Contact dermatitis	7. Contact dermatitis has a moderate degree of heritability and should be included in selection programmes.	Contact dermatitis[ς]	-Breast burns (F/S) -Hock burns (F/S) -Foot-pad dermatitis (F/S)	-Foot-pad lesions: Ekstrand et al., 1998; Michel et al., in press (F/S) -Contact dermatitis: Allain et al., 2009 ; for review Arnould et al., 2009 (F/S)
	8. A standard classification system for contact dermatitis should be developed in Europe.	Contact dermatitis[ς]	See measures for recommendation 7.	
	9. There should be an objective by the industry to decrease the proportion of birds with contact dermatitis over the next 10 years through management and genetic selection.	Contact dermatitis[ς]	See measures for recommendation 7.	
	No recommendations	Skin disease	Breast blisters (F/S)	Breast blisters: for review Arnould et al., 2009 (F/S)

Ascites, pericarditis, sudden death syndrome and spiking mortality syndrome	10. Selection against these conditions, particularly in fast growing lines, should continue and the prevalence needs to be monitored to ensure it remains at a low level	Ascites, pericarditis, sudden death syndrome and spiking mortality syndrome[ς]		-Anatomical and pathological changes, post-mortem inspection, autopsy: Gupta, 2011 (F/S) -Found dead, mortality, daily mortality rate: Council Directive 2007/43/EC (F)
Behavioural restriction	11. Birds should be selected for motivation for activity to increase mobility	Behavioural restriction[ς]	-Qualitative behavioural assessment (QBA) (F) -Plumage cleanliness (F/S)	-Mobility (digital motion detections): Aydin et al., 2010; Kristensen and Cornou, 2011 (F) -Leg problems (see above musculoskeletal disorders) -Motivation for activity: Bokkers and Koene, 2004 (F) -Duration of bouts of different behaviours: e.g., Febrer et al., 2006; Buijs et al., 2010 (F) -Distance walked per unit of time: Leone and Estevez, 2008a, b (F) -"Bird compression" (actual a minimum space occupied by birds): Bokkers et al., 2011 (F)
	12. Management systems that encourage bird mobility should be developed.	Behavioural restriction[ς]	See measures for recommendation 11.	
Thermal discomfort	13. Management techniques should be adapted to avoid heat stress in birds	Thermal discomfort (heat stress)[ς]	Panting[ς] (F)	-Panting[ς]: McLean et al., 2002 (F) -Space distribution: Arnould and Faure, 2004 (F)

	14. Ambient temperature in the environment and genetic strain should be compatible to reduce heat stress. This may also mean reducing the growth rate by management techniques.	Thermal discomfort (heat stress)[c]	See measures for recommendation 13.	
	No recommendation	Thermal discomfort (cold stress)[c]	Huddling (F)	
Respiratory and mucous membrane diseases	15. A standardised system for recording respiratory and mucous membrane diseases at the slaughterhouse should be developed.	Respiratory and mucous membrane diseases (infectious and environmental origin)[c]		-Mortality (F) -Morbidity (F) -Anatomical and pathological changes, post mortem inspection: Aziz and Barnes, 2010 (F/S)
Environmental factors linked to welfare	No recommendations			
Nutrition and feed management, water	No recommendations	Hunger		-Body weight (F/S) -Growth rate, feed consumption (F)
	No recommendations	Thirst	Dehydration measures (shank skin chicks) (F/S)	-Water consumption (F) -Dehydration measures (shank skin chicks): Butterworth and Niebuhr, 2009 (F/S), -Voluntary water consumption: Sprenger et al., 2009 (F)
Digestive function	No recommendation	Digestive dysfunction[c]	Plumage cleanliness (F/S)	Excreta quality (diarrhoea) (F)
Genetic selection and interaction with the environment	16. Welfare traits that are found to be heritable should be included in breeding programmes and selection indices and should also be included in the genetic selection and interaction with the environment studies.			

	17. Genetic diversity should be maintained by breeding companies in order to meet future market demand and to develop lines that can withstand challenging environments.			
	18. Slower growing lines should be used and should be selected further for hot climates.			
	19. There should be standardised (objective) monitoring of welfare in commercial flocks in a system harmonised across different countries, to assess phenotypic trends of various traits as well as the impact of genetic selection on these traits.			
	20. Breeding companies should test and follow-up more closely the ability of the birds to adapt to different kinds of environments from a welfare as well as productivity and marketing perspectives, and not simply on a "no complaints basis". This will provide better information on genetic selection and interaction with the environment for future selection.			
	21. Breeders and farmers should select birds able to adapt to the local environment, so that their welfare is good.			
	22. An independent monitoring system that provides information on welfare and production, should be provided to farmers for them to make a suitable choice of breed for their specific circumstances.			
	23. Genomic selection and other new technologies should be considered when selecting welfare related traits.			
		Emaciation	Emaciation (F/S)	Weight, body condition (F/S)

		Injuries	-Plumage damage (feather pecking; laying hen protocol) (F/S) - Comb pecking wounds (laying hen protocol) (F/S)	-Scratches, wounds, bruising: Allain et al., 2009 (F/S) -Broken wing bones, broken legs: Butterworth and Niebuhr, 2009; Knierim and Gocke, 2003 (F/S) -Aggressive behaviour: Cornetto et al., 2002; Ventura et al., 2012 (F) -Culling due to injuries (F)
		Fear (SCAHAW, 2000)	Avoidance distance test (ADT)	-Fear measures (avoidance distance test, touch test, novel object test): Forkman et al., 2009 (F)
		Other diseases (infectious and non infectious)	-Eye pathologies (laying hen protocol) (F/S) -Parasites (laying hen protocol) (F/S) -Septicaemia (F/S) -Hepatitis (F/S) -Abscesses (sub-cutaneus pus) (F/S)	-Eye irritations and abnormalities (F/S) -Parasitic infections (ecto-parasites, endo-parasites) (F/S) -Septicaemia (F/S) -Hepatitis (F/S) For review, Gregory, 1998; Butterworth and Niebuhr, 2009

§ Letters in parenthesis refer to a measure made on-farm (F) or on-farm and at the slaughter house (F/S).

ç EFSA (2010a)

B. APPENDIX 2: SPECIFICITY (AGREED SCORES) OF ANIMAL-BASED MEASURES PROPOSED IN WELFARE QUALITY® PROTOCOLS - TOR 2

N°	Factor description	Factor characterization	good feeding	good housing		good health												appropriate behaviour	Total number of measures related to the factor and its consequences
			absence of prolonged hunger	comfort around resting	Thermal comfort	absence of injuries				absence of disease								good human-animal relationship	
		Consequence	Emaciation	Plumage cleanliness	Panting	Huddling	Lameness	Hock burn	Foot-pad dermatitis	Breast blister	On-farm mortality	Culls on-farm	Ascites	Dehydration	Septicaemia	Hepatitis	Pericarditis	Abscess (sub-cutaneous pus)	Avoidance distance test (ADT)	
1	High temperatures and humidity	Hyperthermia/ heat stress	1	0	4	0	0	0	0	0	2	0	1	2	0	0	0	0	0	**5**
2A	High stocking density	Movement restriction	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
2B	High stocking density	Reduced behavioural repertoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2C	High stocking density	Heat stress	1	0	4	0	0	0	0	0	2	0	1	2	0	0	0	0	0	**5**

2D	High stocking density	Injury through contact with other birds	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	**4**
2E	High stocking density	Injury through contact with physical structures	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	**4**
2F	High stocking density	Disturbed rest periods	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2G	High stocking density	Increased transmission of infectious diseases	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	**2**
2H	High stocking density	Reduced litter quality (increased chance of I, etc...)	0	2	0	0	0	4	4	1	0	0	0	0	0	0	0	0	0	**4**
2I	High stocking density	Reduced air quality (irritation of respiratory tract and eyes etc)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
3A	Barren environments	Reduced behavioural repertoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
3B	Barren environments	Boredom	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
3C	Barren environments	Frustration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

4A	Wet litter	Atmospheric ammonia irritating the respiratory tract	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
4B	Wet litter	Atmospheric ammonia irritating the eyes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
4C	Wet litter	Pain from hock burn	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	**1**
4D	Wet litter	Pain from foot-pad dermatitis	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	**1**
4E	Wet litter	Pain from breast burn	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	**1**
5A	Poor ventilation	Increased exposure to endotoxins (inflammatory response in mucous membranes), dust, atmospheric ammonia irritating the respiratory tract	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
5B	Poor ventilation	Hyperthermia (temperature and relative humidity)	1	0	4	0	0	0	0	0	2	0	1	2	0	0	0	0	0	**5**

6A	Low light intensity	Reduced behavioural repertoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
6B	Low light intensity	Reduced activity	0	0	0	0	2	1	1	1	0	0	0	0	0	0	0	0	**4**
6C	Low light intensity	Increased time spent in contact with litter	0	1	0	0	1	2	2	2	0	0	0	0	0	0	0	0	**5**
6D	Low light intensity	Reduced visual ability of the bird	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
7	High light intensity (incl. Natural lighting)	Scratches from other birds	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	**4**
8	Light cycle (long photoperiod)	Disturbed rest periods	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
9A	Reduced mobility	Reduced behavioural repertoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
9B	Reduced mobility	Reduced ability to reach feed/water when motivated	3	0	0	0	1	0	0	0	1	1	0	3	0	0	0	0	0	**5**
9C	Reduced mobility	Birds experiencing pain	1	0	0	0	3	0	0	0	1	3	0	0	0	0	0	0	0	**4**

9D	Reduced mobility	Increased time spent in contact with litter	0	1	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0	**5**
10 A	Inappropriate diet	Digestive problems	2	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**4**
10 B	Inappropriate diet	Diet-related bone problems	0	0	0	0	2	0	0	0	1	1	0	0	0	0	0	0	0	**3**
10 C	Inappropriate diet	Cleanliness of plumage	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
10 D	Inappropriate diet	Pain foot-pad dermatitis , hock burn etc (see wet litter)	0	0	0	0	0	4	4	1	0	0	0	0	0	0	0	0	0	**3**
11 A	Unbalanced body conformation	High body mass	0	0	0	0	2	0	0	0	1	1	1	0	0	0	1	0	0	**5**
11 B	Unbalanced body conformation	Pain from FPD	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	**1**
11 C	Unbalanced body conformation	Pain from breast blisters	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	**1**
11 D	Unbalanced body conformation	Lameness	0	0	0	0	4	0	0	0	1	2	0	0	0	0	0	0	0	**3**

12 A	Fast growth rate	Ascites	0	0	0	0	0	0	0	0	2	1	4	0	0	0	0	0	0	**3**
12 B	Fast growth rate	Leg weakness	0	0	0	0	3	0	0	0	1	2	0	0	0	0	0	0	0	**3**
12 C	Fast growth rate	Sudden death syndrome	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	**1**
12 D	Fast growth rate	Skeletal disorders	0	0	0	0	3	0	0	0	1	2	0	0	0	0	0	0	0	**3**
12E	Fast growth rate	Muscle disorders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
12F	Fast growth rate	High body mass	0	0	0	0	2	0	0	0	1	1	1	0	0	0	1	0	0	**5**
12 G	Fast growth rate	Reduced behavioural repertoire	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
12 H	Fast growth rate	Inactivity (long periods of time in contact with litter)	0	1	0	0	1	2	2	2	0	0	0	0	0	0	0	0	0	**5**
13	Crusted litter	Pain from breast blisters	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	**1**

HOW MANY FACTOR'S CONSEQUENCES ARE COVERED BY AN ANIMAL-BASED WELFARE QUALITY® MEASURE?	**6**	**6**	**3**	**0**	**13**	**7**	**8**	**9**	**21**	**17**	**6**	**4**	**3**	**0**	**2**	**3**	**0**	

C. APPENDIX 3: SENSITIVITY (AGREED SCORES) OF ANIMAL-BASED MEASURES PROPOSED IN WELFARE QUALITY® PROTOCOLS - TOR 2

N°	Factor description	factors characterization	good feeding	good housing		good health												appropriate behaviour	Total number of measures related to the factors and its consequences
		Consequence	absence of prolonged hunger	comfort around resting	Thermal comfort		absence of injuries				absence of disease							good human-animal relationship	
			Emaciation	Plumage cleanliness	Panting	Huddling	Lameness	Hock burn	Foot-pad dermatitis	Breast blister	On-farm mortality	Culls on-farm	Ascites	Dehydration	Septicaemia	Hepatitis	Pericarditis	Abscess (sub-cutaneous pus)	Avoidance distance test (ADT)	
1	High temperatures and humidity	Hyperthermia/heat stress	1	0	4	0	0	0	0	0	3	0	1	3	0	0	0	0	0	**5**
2A	High stocking density	Movement restriction	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	**1**
2B	High stocking density	Reduced behavioural repertoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2C	High stocking density	Heat stress	1	0	4	0	0	0	0	0	1	0	1	3	0	0	0	0	0	**5**

2D	High stocking density	Injury through contact with other birds	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	**4**
2E	High stocking density	Injury through contact with physical structures	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	**4**
2F	High stocking density	Disturbed rest periods	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2G	High stocking density	Increased transmission of infectious diseases	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	**2**
2H	High stocking density	Reduced litter quality (increased chance of I, etc...)	0	2	0	0	0	4	4	3	0	0	0	0	0	0	0	0	0	**4**
2I	High stocking density	Reduced air quality (irritation of respiratory tract and eyes etc)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
3A	Barren environments	Reduced behavioural repertoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
3B	Barren environments	Boredom	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
3C	Barren environments	Frustration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

4A	Wet litter	Atmospheric ammonia irritating the respiratory tract	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
4B	Wet litter	Atmospheric ammonia irritating the eyes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
4C	Wet litter	Pain from hock burn	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	**1**
4D	Wet litter	Pain from foot-pad dermatitis	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	**1**
4E	Wet litter	Pain from breast burn	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	**1**
5A	Poor ventilation	Increased exposure to endotoxins (inflammatory response in mucous membranes), dust, atmospheric ammonia irritating the respiratory tract	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
5B	Poor ventilation	Hyperthermia (temperature and relative humidity)	1	0	4	0	0	0	0	0	2	0	2	2	0	0	0	0	0	**5**

6A	Low light intensity	Reduced behavioural repertoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
6B	Low light intensity	Reduced activity	0	0	0	0	2	1	1	1	0	0	0	0	0	0	0	0	**4**
6C	Low light intensity	Increased time spent in contact with litter	0	1	0	0	2	2	2	2	0	0	0	0	0	0	0	0	**5**
6D	Low light intensity	Reduced visual ability of the bird	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
7	High light intensity (incl. Natural lighting)	Scratches from other birds	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	**4**
8	Light cycle (long photoperiod)	Disturbed rest periods	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
9A	Reduced mobility	Reduced behavioural repertoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
9B	Reduced mobility	Reduced ability to reach feed/water when motivated	2	0	0	0	2	0	0	0	2	3	0	2	0	0	0	0	0	**5**
9C	Reduced mobility	Birds experiencing pain	1	0	0	0	2	0	0	0	2	3	0	0	0	0	0	0	0	**4**

9D	Reduced mobility	Increased time spent in contact with litter	0	0	0	0	3	2	2	2	0	0	0	0	0	0	0	0	0	**4**
10 A	Inappropriate diet	Digestive problems	3	2	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	**4**
10B	Inappropriate diet	Diet-related bone problems	0	0	0	0	3	0	0	0	1	2	0	0	0	0	0	0	0	**3**
10C	Inappropriate diet	Cleanliness of plumage	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
10 D	Inappropriate diet	Pain foot-pad dermatitis , hock burn etc (see wet litter)	0	0	0	0	0	4	4	3	0	0	0	0	0	0	0	0	0	**3**
11 A	Unbalanced body conformation	High body mass	0	0	0	0	3	0	0	0	3	1	1	0	0	0	1	0	0	**5**
11B	Unbalanced body conformation	Pain from FPD	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	**1**
11C	Unbalanced body conformation	Pain from breast blisters	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	**1**

11 D	Unbalanced body conformation	Lameness	0	1	0	0	4	0	0	0	3	3	0	0	0	0	0	0	0	**4**
12 A	Fast growth rate	Ascites	0	0	0	0	0	0	0	0	3	2	4	0	0	0	0	0	0	**3**
12B	Fast growth rate	Leg weakness	0	0	0	0	4	0	0	0	2	3	0	0	0	0	0	0	0	**3**
12C	Fast growth rate	Sudden death syndrome	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	**1**
12 D	Fast growth rate	Skeletal disorders	0	0	0	0	4	0	0	0	2	3	0	0	0	0	0	0	0	**3**
12E	Fast growth rate	Muscle disorders	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
12F	Fast growth rate	High body mass	0	0	0	0	3	0	0	0	3	1	2	0	0	0	1	0	0	**5**
12 G	Fast growth rate	Reduced behavioural repertoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
12 H	Fast growth rate	Inactivity (long periods of time in contact with litter)	0	1	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0	**5**
13	Crusted litter	Pain from breast blisters	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	**1**

HOW MANY FACTOR'S CONSEQUENCE ARE COVERED BY AN ANIMAL-BASED WELFARE WALITY® MEASURE?	**6**	**6**	**3**	**0**	**13**	**7**	**8**	**9**	**21**	**17**	**6**	**4**	**3**	**0**	**2**	**3**	**0**	

D. APPENDIX 4: LINK (1) OR NO LINK (0) BETWEEN FACTORS AND NON ANIMAL-BASED MEASURES PROPOSED IN WELFARE QUALITY® PROTOCOLS - TOR 2

N°	Factor description	Consequence	good feeding	good housing			Number of resource-based or management-based measures related to the factor
			absence of prolonged thirst	comfort around resting		ease of movement	
			Drinker space (birds per drinker)	Litter quality	Dust sheet test	Stocking density	
1	High temperatures and humidity	Hyperthermia/heat stress	0	0	0	0	0
2A	High stocking density	Movement restriction	0	0	0	1	1
2B	High stocking density	Reduced behavioural repertoire	0	0	0	1	1
2C	High stocking density	Hyperthermia/heat stress	0	0	0	1	1
2D	High stocking density	Injury through contact with other birds	0	0	0	1	1
2E	High stocking density	Injury through contact with physical structures	0	0	0	1	1
2F	High stocking density	Disturbed rest periods	0	0	0	1	1
2G	High stocking density	Increased transmission of infectious diseases	0	0	0	1	1
2H	High stocking density	Reduced litter quality (increased chance of I, etc...)	0	1	0	1	2
2I	High stocking density	Reduced air quality (irritation of respiratory tract and eyes etc)	0	1	1	1	3
3A	Barren environments	Reduced behavioural repertoire	0	0	0	0	0
3B	Barren environments	Boredom	0	0	0	0	0
3C	Barren environments	Frustration	0	0	0	0	0
4A	Wet litter	Atmospheric ammonia irritating the respiratory tract	0	1	0	0	1
4B	Wet litter	Atmospheric ammonia irritating the eyes	0	1	0	0	1
4C	Wet litter	Pain from hock burn	0	1	0	0	1
4D	Wet litter	Pain from foot-pad dermatitis	0	1	0	0	1
4E	Wet litter	Pain from breast burn	0	1	0	0	1

5A	Poor ventilation	Increased exposure to endotoxins (inflammatory response in mucous membranes), dust, atmospheric ammonia irritating the respiratory tract	0	1	1	0	2
5B	Poor ventilation	Hyperthermia (temperature and relative humidity)	0	0	0	0	0
6A	Low light intensity	Reduced behavioural repertoire	0	0	0	0	0
6B	Low light intensity	Reduced activity	0	0	0	0	0
6C	Low light intensity	Increased time spent in contact with litter	0	0	0	0	0
6D	Low light intensity	Reduced visual ability of the bird	0	0	0	0	0
7	High light intensity (incl. Natural lighting)	Scratches from other birds	0	0	0	0	0
8	Light cycle (long photoperiod)	Disturbed rest periods	0	0	0	0	0
9A	Reduced mobility	Reduced behavioural repertoire	0	0	0	0	0
9B	Reduced mobility	Reduced ability to reach feed/water when motivated	1	0	0	0	1
9C	Reduced mobility	Birds experiencing pain	0	0	0	0	0
9D	Reduced mobility	Increased time spent in contact with litter	0	0	0	0	0
10A	Inappropriate diet	Digestive problems	0	1	0	0	1
10B	Inappropriate diet	Diet-related bone problems	0	0	0	0	0
10C	Inappropriate diet	Cleanliness of plumage	0	1	0	0	1
10D	Inappropriate diet	Pain foot-pad dermatitis, hock burn etc (see wet litter)	0	1	0	0	1
11A	Unbalanced body conformation	High body mass	0	0	0	0	0
11B	Unbalanced body conformation	Pain from FPD	0	0	0	0	0
11C	Unbalanced body conformation	Pain from breast blisters	0	0	0	0	0
11D	Unbalanced body conformation	Lameness	0	0	0	0	0
12A	Fast growth rate	Ascites	0	0	0	0	0
12B	Fast growth rate	Leg weakness	0	0	0	0	0
12C	Fast growth rate	Sudden death syndrome	0	0	0	0	0

12D	Fast growth rate	Skeletal disorders	0	0	0	0	0
12E	Fast growth rate	Muscle disorders	0	0	0	0	0
12F	Fast growth rate	High body mass	0	0	0	0	0
12G	Fast growth rate	Reduced behavioural repertoire	0	0	0	0	0
12H	Fast growth rate	Inactivity (long periods of time in contact with litter)	0	0	0	0	0
13	Crusted litter	Pain from breast blisters	0	1	0	0	1
HOW MANY FACTORS ARE COVERED BY A NON ANIMAL-BASED WELFARE QUALITY® MEASURE?			1	12	2	9	

E. APPENDIX 5: FACTOR CONTROL POTENTIAL THROUGH MANAGEMENT BETWEEN FLOCKS AND WITHIN FLOCK – TOR 4

N°	Factor description	FACTOR control potential through management BETWEEN FLOCKS				FACTOR control potential through management WITHIN FLOCK				Magnitude*	Welfare Impact*	Risk score*
		Mean	Median	Min	Max	Mean	Median	Min	Max			
1	High temperatures and humidity	4.33	4.0	4	5	3.67	4.0	3	4	1.9	0.2	0
2	High stocking density	4.50	5.0	3	5	1.67	1.5	1	3	29.2	9.5	8.5
3	Barren environments	4.17	4.0	3	5	3.33	3.5	2	4	13.3	2.0	1.2
4	Wet litter	4.17	4.0	3	5	2.50	3.0	1	4	11.7	2.9	2.6
5	Poor ventilation	4.33	4.0	4	5	3.17	3.0	2	5	10.5	0.8	0.2
6	Low light intensity	4.83	5.0	4	5	4.17	4.0	3	5	26.7	6.7	4.7
7	High light intensity (incl. Natural lighting)	4.33	4.5	3	5	3.17	3.0	2	4	6.7	0.5	0
8	Light cycle (long photoperiod)	4.83	5.0	4	5	4.50	4.5	4	5	40	6.0	0.6
9	Reduced mobility	2.33	2.5	1	3	1.33	1.0	0	3	29.2	5.8	0.6
10	Inappropriate diet	4.83	5.0	4	5	2.67	2.5	1	4	32.5	6.5	0.7
11	Unbalanced body conformation	3.17	3.0	2	4	0.67	1.0	0	1	37.9	9.5	6.6
12	Fast growth rate	3.17	3.5	1	4	2.00	2.0	1	4	29.2	5.8	4.1
13	Crusted litter	4.50	5.0	3	5	3.00	3.0	2	4	40.0	3.0	1.4

*Scores from EFSA, 2010a

F. APPENDIX 6: CONSEQUENCE CONTROL POTENTIAL THROUGH MANAGEMENT WITHIN FLOCK - TOR 4

N°	Factor description	Consequence	CONSEQUENCE control potential through management WITHIN FLOCK				Welfare impact*	Magnitude*
			Mean	Median	Min	Max		
1	High temperatures and humidity	Hyperthermia/heat stress	3.67	4	2	5	3.1	21.0
2A	High stocking density	Movement restriction	1.33	1	0	3	5.3	13.3
2B		Reduced behavioural repertoire	1.20	1	0	2	4.0	10.0
2C		Hyperthermia/heat stress	2.60	3	1	4	3.3	13.3
2D		Injury through contact with other birds	1.80	2	1	3	0.4	6.7
2E		Injury through contact with physical structures	2.40	2	1	4	0.1	1.7
2F		Disturbed rest periods	1.40	1	0	3	10.0	40.0
2G		Increased transmission of infectious diseases	0.00	0	0	0	7.8	60.0
2H		Reduced litter quality (increased chance of FPD, etc...)	3.20	4	1	4	17.3	53.3
2I		Reduced air quality (irritation of respiratory tract and eyes etc)	3.40	4	2	4	14.7	53.3
3A	Barren environments	Reduced behavioural repertoire	1.33	1.5	0	2	3.8	33.3
3B		Boredom	1.33	1.5	0	2	12.9	33.3
3C		Frustration	1.17	1.5	0	2	2.0	13.3
4A	Wet litter	Atmospheric ammonia irritating the respiratory tract	2.33	3	1	3	2.7	13.3

4B		Atmospheric ammonia irritating the eyes	2.33	3	1	3	2.7	13.3
4C		Pain from hock burn	2.00	2	1	3	5.4	25.0
4D		Pain from foot-pad dermatitis	2.00	2	1	3	4.3	13.3
4E		Pain from breast burn	2.00	2	1	3	1.3	10.0
5A	Poor ventilation	Increased exposure to endotoxins (inflammatory response in mucous membranes), dust, atmospheric ammonia irritating the respiratory tract	1.40	1	1	2	1.5	13.3
5B		Hyperthermia (temperature and relative humidity)	1.40	1	1	3	1.5	13.3
6A	Low light intensity	Reduced behavioural repertoire	1.80	2	1	2	8.0	40.0
6B		Reduced activity	1.60	2	1	2	10.7	53.3
6C		Increased time spent in contact with litter	1.60	2	0	2	10.7	53.3
6D		Reduced visual ability of the bird	0.40	0	0	1	8.7	53.3
7	High light intensity (incl. Natural lighting)	Scratches from other birds	2.67	2.5	2	4	1.1	20.8
8	Light cycle (long photoperiod)	Disturbed rest periods	1.60	2	0	3	4.5	40.0
9A	Reduced mobility	Reduced behavioural repertoire	0.80	1	0	2	21.3	53.3
9B		Reduced ability to reach feed/water when motivated	2.60	3	2	3	13.3	53.3

9C		Birds experiencing pain	0.40	0	0	2	13.3	53.3
9D		Increased time spent in contact with litter	1.40	2	0	2	21.3	53.3
10A	Inappropriate diet	Digestive problems	2.00	1	1	4	7.0	46.7
10B		Diet-related bone problems	2.40	2	1	4	10.0	40.0
10C		Cleanliness of plumage	2.83	3	1	4	9.3	46.7
10D		Pain foot-pad dermatitis, hock burn etc (see wet litter)	3.00	3.5	1	4	10.7	53.3
11A	Unbalanced body conformation	High body mass	1.80	1	1	3	17.5	40.0
11B		Pain from FPD	2.80	3	2	4	10.7	53.3
11C		Pain from breast blisters	2.80	3	2	4	1.9	25.0
11D		Lameness	2.40	2	2	3	23.3	53.3
12A	Fast growth rate	Ascites	2.00	2	1	3	0.4	13.3
12B		Leg weakness	1.60	2	1	2	8.7	53.3
12C		Sudden death syndrome	1.20	1	1	2	1.3	25.2
12D		Skeletal disorders	1.40	1	1	2	6.0	53.3
12E		Muscle disorders	1.25	1	1	2	4.2	46.7
12F		High body mass	1.20	1	0	3	8.3	13.3
12G		Reduced behavioural repertoire	2.40	3	1	3	25.0	40.0
12H		Inactivity (long periods of time in contact with litter)	2.20	2	2	3	41.7	66.7
13	Crusted litter	Pain from breast blisters	1.20	2	0	2	1.7	40.0

*Scores from EFSA, 2010a

GLOSSARY

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

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

Broiler: a type of chicken (Gallus gallus domesticus) bred for meat production.

Contact dermatitis: comprises those diseases arising from skin contact with wet litter e.g. foot-pad dermatitis (pododermatitis), breast blisters (sometimes known as breast burns), hock burns.

Culling: the killing of birds that are not usable or are low-producing.

Environment: external factors that affect an animal.

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

Genetic Selection: the process of deciding which animals will be parents of the next generation based on some pre-determined criterion.

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

Lameness: an abnormal gait may or may not involve pain.

Leg weakness: a condition where the legs (including joints, bones, muscles, tendons etc) are affected and may predispose to lameness.

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

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

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

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

Pedigree (Elite) stock: birds used for breeding great grand-parent (GGP) stock and the generations prior to these.

Qualitative Behaviour Assessment (QBA): of welfare is carried out by observing the target individuals in a flock and using descriptors for their behaviour, such as 'calm,' 'aggressive', or 'sociable'. Integrating these observations provides a measure of the emotional state of the individual.

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

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

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

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

Sensitivity: the probability that the consequence is detected by the animal-based measure when the adverse effect is present in the population (i.e. probability of a correct positive test). A score of 0, or a low score, implies no or little sensitivity and a poor chance that the animal-based measure will detect the problem if it is there, whereas a high score implies there is good sensitivity and a good chance of detecting the problem.

Specificity: is defined as the degree with which the animal-based measure is related to a single welfare consequence or whether it relates (responds) to several different consequences (i.e. probability of a correct negative test). A score of 0 or a low score implies no or poor specificity indicating that the animal-based measure could be the response of many welfare consequences, whereas a high score implies good specificity indicating that the measure is a response to one or very few consequences.

Sudden death syndrome (SDS): birds (broiler chickens) that die suddenly with no other obvious pathology.

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

Trait: any measurable or observable characteristic of an animal.

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

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

Welfare measure: a category of observation, recording or evaluation used to assess an animal's welfare. These are in general animal-based but measures of housing and management may be predictors of changes in 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.

Welfare: the welfare of an individual is its state as regards its attempts to cope with its environment.