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Welfare of broilers on farm

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Abstract

This Scientific Opinion considers the welfare of domestic fowl (*Gallus gallus*) related to the production of meat (broilers) and includes the keeping of day-old chicks, broiler breeders, and broiler chickens. Currently used husbandry systems in the EU are described. Overall, 19 highly relevant welfare consequences (WCs) were identified based on severity, duration and frequency of occurrence: 'bone lesions', 'cold stress', 'gastro-enteric disorders', 'group stress', 'handling stress', 'heat stress', 'isolation stress', 'inability to perform comfort behaviour', 'inability to perform exploratory or foraging behaviour', 'inability to avoid unwanted sexual behaviour', 'locomotory disorders', 'prolonged hunger', 'prolonged thirst', 'predation stress', 'restriction of movement', 'resting problems', 'sensory under- and overstimulation', 'soft tissue and integument damage' and 'umbilical disorders'. These WCs and their animal-based measures (ABMs) that can identify them are described in detail. A variety of hazards related to the different husbandry systems were identified as well as ABMs for assessing the different WCs. Measures to prevent or correct the hazards and/or mitigate each of the WCs are listed. Recommendations are provided on quantitative or qualitative criteria to answer specific questions on the welfare of broilers and related to genetic selection, temperature, feed and water restriction, use of cages, light, air quality and mutilations in breeders such as beak trimming, de-toeing and comb dubbing. In addition, minimal requirements (e.g. stocking density, group size, nests, provision of litter, perches and platforms, drinkers and feeders, of covered veranda and outdoor range) for an enclosure for keeping broiler chickens (fast-growing, slower-growing and broiler breeders) are recommended. Finally, 'total mortality', 'wounds', 'carcass condemnation' and 'footpad dermatitis' are proposed as indicators for monitoring at slaughter the welfare of broilers on-farm.

Keywords: broilers, on farm welfare, husbandry systems, welfare consequences, animal-based measures, end the cage age, mutilations

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Summary

In the framework of its Farm to Fork Strategy, the European Commission is undertaking a comprehensive evaluation of the animal welfare legislation, including Council Directive 2007/43/EC that lies down the minimum rules for the protection of chickens kept for meat production. This Directive currently does not apply to hatcheries, holdings with fewer than 500 chickens, holdings with only breeding stock and holdings with free-range access. A European Citizen Initiative (ECI) 'end the cage age' called for banning the use of (furnished) cages in species for which specific EU legislation exists (laying hens, pigs and calves). Against this background, the European Commission requested the European Food Safety Authority (EFSA) to give an independent view on the protection of broilers during the different phases of the production cycle. This Scientific Opinion includes the welfare assessment of the following broiler categories: day-old chicks, broiler breeders and broilers for meat production. Based on the existing literature, reports and expert knowledge elicitations, this Opinion answers the general Terms of Reference (ToRs) and describes the currently used husbandry systems/ practices for all broiler categories and the related welfare consequences (WCs) as well as associated animal-based measures (ABMs) (general ToRs). In addition, the Scientific Opinion identifies the hazards leading to these WCs and provides recommendations to prevent or correct the hazards and/or mitigate the WCs. The European Commission also requested EFSA to assess specific scenarios related to the welfare of fast-growing broilers in barns and the risk associated with air and floor temperature, access to feed and water, space allowance and air quality. For broiler breeders, the risks associated with housing in (individual) cages and practices such as feed restriction and/or mutilations (beak trimming, de-toeing, comb dubbing, de-clawing) are also assessed. For day-old chicks, welfare issues related to hatching on-farm and in hatcheries are assessed. Finally, the assessment of ABMs that are or can be collected at slaughterhouses to monitor the welfare level of broilers on-farm is described. The uncertainty analysis for this Scientific Opinion is restricted to the data collection and the sources of information such as the possible lack of (representative) data on husbandry systems and their related WCs and ABMs.

The EU is one of the world's biggest producers of poultry meat with around 6 billion broiler chickens being reared for meat every year resulting in 13.3 million tonnes of poultry meat. Overall, broiler farming in the EU is characterised by high intensification with the majority of birds reared indoor, at high stocking densities and where birds are bred for rapid muscular growth, and slaughtered within 28–42 days of age.

Currently used husbandry systems (with or without outdoor access) and management practices are described. For day-old chicks two systems are included (hatched on farm and hatched in hatcheries). Broilers are mainly kept in floor systems (barns) with or without covered veranda and in mobile systems with outdoor free range. Cage systems (individual unfurnished and collective cages) are used for broiler breeders (grandparent, great grandparent and pure lines). Floor systems with raised slats called single tier and with multi-tiers (parent breeding) are also described.

The occurrence, severity and duration of each WC vary depending on the husbandry system and the bird category. Out of the total 19 WCs, seven WCs were identified as highly relevant for day-old chicks: 'cold stress', 'prolonged hunger', 'prolonged thirst', 'handling stress', 'resting problems', 'umbilical disorders' and 'sensory under- and/or overstimulation'. For both broiler chickens and broiler breeders husbandry systems, six WCs were identified as highly relevant: 'resting problems', 'group stress', 'inability to perform comfort behaviour', 'inability to perform exploratory or foraging behaviour', 'restriction of movement' and 'soft tissue and integument damage'. Additional six highly relevant WCs were identified in broiler breeder systems compared to broiler chicken systems: 'isolation stress', 'prolonged hunger', 'prolonged thirst', 'bone lesions', 'handling stress', and the 'inability to avoid unwanted sexual behaviour'. In addition four highly relevant welfare consequences were considered as highly relevant for broiler chickens: 'cold stress', 'heat stress', 'locomotory disorders' and 'gastro-enteric disorders'.

ABMs were identified for each of the highly relevant WCs, including behavioural, clinical and physiological ABMs. A definition of each ABM, how to measure it and its interpretation are provided in this Scientific Opinion. Qualitative evaluations of sensitivity and specificity of ABMs are also provided. Some of the ABMs are relevant to more than one WC (iceberg indicators) and can be used for general welfare screening purposes, often used to get an impression of the welfare status of a flock. These should be included in any welfare assessment scheme. The 'iceberg indicators' identified, regardless the bird category, were: 'distress calls', 'feather and body dirtiness', 'lethargy', 'total mortality', 'stereotypic behaviour', 'injurious pecking' (severe feather pecking, cannibalism), 'plumage damage',

'fear response', 'piling and smothering', 'wounds', 'hock burn', 'footpad dermatitis (FPD)' and 'walking impairment'.

A wide variety of hazards were identified for the different WCs and the currently used husbandry systems. The major hazards that lead to reduced welfare in broilers are: genetic selection for fast growing rate, high stocking density, absence of litter or poor litter quality, too high effective temperature, absence or sub-optimally designed perches, and sub-optimal light management. Potential preventive and corrective measures towards hazards and mitigative measures for each WC are described. High stocking density leads to many WCs impacting on-farm mortality, thermal discomfort, locomotory disorders, inability to perform comfort behaviour, inability to perform foraging and exploratory behaviour, and increased soft tissue and integument damage.

In this Scientific Opinion, the impact of stocking density in broiler chickens on two reference ABMs (FPD and percentage of time walking) was assessed by expert knowledge elicitation. In addition, a second approach used a behavioural model to estimate the space allowance needed to meet their behavioural needs. The maximal stocking density above which FPD score will increase, walking ability will be reduced and behavioural needs realisation is impaired because of lack of space is 11 kg/m^2 with 66–100% certainty. At all times, dry and friable litter should be available at the useable area. The use of a covered veranda and the provision of elevated structures (with easy access/ramps) are highly recommended. Air quality in a broiler barn is determined by a complex interaction between factors such as ventilation, stocking density, litter quality, and the age and health status of the birds. Ammonia should not exceed 15 ppm. Due to lack of evidence no specific recommendations could be made with regard to CO_2 and dust. Broiler chickens should have easy access to the feeding and drinking systems. The environment should be illuminated at least with 20 lux minimum, with functional areas of resting (e.g. dark brooders) offering intensities down to 0.5 lux. Chicks should be provided with 23 h of light up to day 3 of life with a gradual decrease of the photoperiod to 16–17 h at day 7. From systems with outdoor access and/or covered verandas, there is evidence that daylight has positive effects on the activity of broilers. A covered veranda is recommended for all bird categories, while an outdoor range is considered especially useful in combination with a covered veranda. If an outdoor range is provided, natural vegetation (e.g. grass, bushes, and trees for shelter) should be foreseen and at least 70% of the range should be covered with vegetation of which 50% should be trees and bushes.

Mutilations such as beak trimming, de-toeing/clawing and comb dubbing are widely performed across the EU on chicks destined to be broiler breeders to prevent soft tissue and integument damage caused by injurious pecking and during too frequent mating. It is recommended not to perform any type of mutilation. Injurious pecking and wounds and scratches inflicted by males on females during mating can to some extent be prevented when husbandry practices, housing system and management are appropriate. To that end regular monitoring of the body status of females and implementing of management practices to avoid injurious pecking and allow females to avoid unwanted sexual behaviour can be applied.

Selective breeding has traditionally focused on economic traits such as high growth rate, leading to significant welfare problems such as musculoskeletal disorders reducing walking ability of broiler chickens that, in turn, impair access to feed and water and performance of natural behaviours. In male breeders, selection for mating activity has led to overmating that damages the feathers and skin of females causing wounds. Additionally, the high growth rate makes feed restriction (leading to prolonged hunger) necessary in broiler breeders. Selection for more robust breeds with ameliorated abilities to cope with the management systems in use and/or the use of slower-growing hybrids is recommended, with particular attention to breeds with lower mortality, reduced leg weakness and reduced susceptibility to cardiovascular diseases.

ABMs that can be used in slaughterhouses to monitor the level of welfare of broiler flocks on-farm are identified and described in this Scientific Opinion. The following ABMs were considered the most appropriate for further development: indicators used for 'carcass condemnation', 'total on-farm mortality' (culls on-farm and on-farm mortality recorded weekly), 'wounds' and 'FPD'. For all ABMs, it is considered necessary to develop harmonised and standardised scoring systems and protocols to monitor and benchmark the welfare of broilers on-farm across different regions/countries. The automated monitoring of some of these ABMs at the slaughterhouse is currently applied (e.g. 'FPD' and 'wounds').

To improve broiler chickens' welfare, the recommendations considered urgent to apply are: a limitation in growth rate (maximum 50 g/day), reduction of the stocking density to a maximum of 11 kg/m^2, provision of dry and friable litter at all times, and provision of a covered veranda available from 2 weeks of age for broilers and broiler breeders as well as provision of elevated platforms, dark brooders for day-old chicks, and perches/elevated structures for breeders and broilers. It is also recommended to avoid all forms of mutilations, feed restriction and the use of cages in broiler breeders. In addition, concerning the assessment of on-farm welfare at slaughter, it is recommended to harmonise the assessment of the following ABMs: 'wounds', 'carcass condemnation', 'total on-farm mortality' and 'FPD'.

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

In the framework of its Farm to Fork strategy, the Commission will start a comprehensive evaluation of the animal welfare legislation. This will include the following acts:

1) Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes[1];
2) Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens[2];
3) Council Directive 2008/119/EC of 18 December 2008 laying down minimum standards for the protection of calves[3] (Codified version);
4) Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs[4] (Codified version);
5) Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production[5];
6) Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97[6];
7) Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing[7].

These acts are based on Scientific Opinions that are outdated. In the context of this evaluation, and possible drafting of legislative proposals, the Commission needs new opinions that reflect the most recent scientific knowledge.

Since the EFSA has already accepted mandates on the protection of animals at the time of killing, no opinion is requested on this topic.

Furthermore, a European Citizen Initiative (ECI) "end of the cage age" was registered in September 2018. The ECI calls for banning the use of cages or individual stalls in particular for laying hens, pigs and calves, where specific EU legislation exists.

The concept of "cage" is not precisely defined in the legislation. In its common meaning "cage" means a box or enclosure having some openwork (e.g., wires, bars) for confining or carrying animals. It can cover either individually confined animals or animals kept in group in a limited space.

Against this background, the Commission would like to request the EFSA to review the available scientific publications and possibly other sources to provide a sound scientific basis for future legislative proposals.

This request is about the protection of domestic fowl (species *Gallus gallus*) related to the production of meat.

The latest Scientific Opinion, which was used for the current legislation, was published in 2000. Since then, the EFSA adopted opinions on the welfare of broilers and broiler breeders in 2010 and 2012 (EFSA AHAW Panel, 2010, 2012).

The Commission therefore considers opportune to request EFSA to give an independent view on the protection of domestic fowl (species *Gallus gallus*) related to the production of meat.

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[1] 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.
[2] Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens.OJ L 203, 3.8.1999, p. 53.
[3] Council Directive 2008/119/EC of 18 December 2008 laying down minimum standards for the protection of calves (Codified version). OJ L 10, 15.1.2009, p. 7.
[4] Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs (Codified version). OJ L 47, 18.2.2009, p. 5.
[5] 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, 12.7.2007, p. 19.
[6] Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97. OJ L 3, 5.1.2005, p. 1.
[7] Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing. OJ L 303, 18.11.2009, p. 1 Ref. Ares (2020)2855277 - 03/06/2020.

The request includes the different phases of the production cycle:

- The keeping of day-old chicks (up to 72 h of age);
- The keeping of broiler breeders.
- The keeping of chickens for meat production.

The killing of animals on farm is not part of the request.
For this request, the EFSA will for each category of animals:

- Describe, based on existing literature and reports, the current husbandry systems and practices of keeping them, (General ToR 1)
- Describe the relevant welfare consequences. Relevance will not need to be based on a comprehensive risk assessment, but on EFSA's expert opinion regarding the severity, duration and occurrence of each welfare consequence, (General ToR 2)
- Define qualitative or quantitative measures to assess the welfare consequences (animal-based measures) (General ToR 3)
- Identify the hazards leading to these welfare consequences, (General ToR 4)
- Provide recommendations to prevent, mitigate or correct the welfare consequences (resource and management-based measures) (General ToR 5)

For the following scenarios, the Commission has identified practical difficulties or insufficient information in ensuring the welfare of animals. At least for them, the EFSA is asked to propose detailed animal-based measures and preventive and corrective measures with, where possible, either qualitative (yes/no question) or quantitative (minimum/maximum) criteria (i.e., requirements to prevent and/or mitigate the welfare consequences):

(Specific ToR 1) The welfare of fast-growing chickens in barns and the risks associated with:

a) air and floor temperature,
b) access to feed and water,
c) space allowance,
d) air quality;

(Specific ToR 2) The assessment of Animal Based Measures collected in slaughterhouses (such as footpad dermatitis) to monitor the level of welfare on broiler farms.
(Specific ToR 3) The welfare of broiler breeders and the risks associated with:

a) housing in (individual) cages,
b) the practice of routine mutilation (beak trimming, de-toeing, comb dubbing, de-clawing...)
c) the feed restriction;

(Specific ToR 4) The welfare of day-old chick until they reach the rearing or breeding farms:

a) hatchery conditions,
b) transport conditions;

1.2. Interpretation of the Terms of Reference

This Scientific Opinion considers the following three 'categories of birds' welfare of day-old chicks, broiler chickens and broiler breeders on farm. The welfare during transport and on-farm killing of chickens is not part of the request.

A welfare assessment consists of two components, i.e. the risk assessment, with identification of the negative welfare consequences (adverse effects) that occur to an animal in response to a factor, and the benefit assessment, with identification of positive welfare consequences. In this Scientific Opinion, however, the focus is on the assessment of adverse effects only, which are called 'welfare consequences'.

In the context of animal welfare assessment, the scientific literature on chicken welfare often references to chickens' behavioural needs, and preferences. These terms have been defined by (Rowe and Mullan, 2022) and are used as such in this Scientific Opinion. A behavioural need is related to behaviours, which are part of the natural repertoire and are primarily motivated by internal causal factors (Weeks and Nicol, 2006). Animals will attempt to perform these behaviours even in the absence of an optimum environment or the necessary resource. For example, the performance of 'sham' dustbathing on a wire floor, in the absence of a preferred substrate, is a good example of a 'behavioural need'. A *behavioural preference* indicates the relative outcome when a bird has been provided a choice (e.g. the choice between different foraging, nesting or dustbathing substrates, or the choice for perches of different characteristics).

Concerning the general ToRs, the first step was to identify and describe the most relevant husbandry systems (i.e. systems existing at commercial level in EU) for day-old chicks, broiler chickens and broiler breeders. They were identified and described in detail in Section 3.3.

The mandate, in its background, is describing cage in the following terms:

> 'In its common meaning "cage" means a box or enclosure having some openwork (e.g., wires, bars) for confining or carrying animals. It can cover either individually confined animals or animals kept in group in a limited space'.

In addition, the background states about the European Citizen Initiative End the Cage Age, which calls for the banning of use of cages of broiler breeders.

This above-mentioned description in the mandate is very broad, vague and ambiguous as it may cover different husbandry systems. In the present Scientific Opinion, the most relevant husbandry systems were identified and described but not only the ones called in the common usage 'as cages' (e.g. broiler breeders in individual cages and collective cages).

For day-old chicks, two systems were identified: day-old chicks hatched in hatchery and day-old chicks hatched on farm. For broiler chickens, different types of barn systems with or without access to covered veranda and/or outdoor free range were described. Broiler breeders were the only category of bird for which so-called 'cage' systems were identified.

As a second step, the Scientific Opinion fully lists the different welfare consequences that have been identified as highly relevant (see Section 3.4.1) across the husbandry systems.

The Scientific Opinion details in Section 3.4.2 the welfare consequences and how these are linked to the different animal categories and husbandry systems. The recommended animal-based measures (ABMs), for each of the welfare consequences are listed and for each ABM the following characteristics were provided: how to measure and interpret the ABM and if possible, sensitivity and specificity of the ABM. For each welfare consequence, the hazards and preventive and corrective measures are described. Hazards should be interpreted as risk factors or exposure variables leading to the welfare consequences. Preventive, corrective and mitigative measures should be interpreted interventions that can be taken to prevent or correct (e.g. reduce or remove impact) the hazard or mitigate the welfare consequence.

Furthermore, many of the highly relevant welfare consequences identified in this opinion have a common hazard (or exposure factor, e.g. inappropriate litter). Therefore, in addition to the recommendations for each different welfare consequence, this Scientific Opinion proposes to deliver recommendations regarding exposure factors, in a holistic way. These recommendations specify the needs of each category of bird and how they can be fulfilled in terms of 'key parameters of the minimal enclosure' (Section 3.5). In this way, the recommendations define the minimal technical specification of the enclosure preventing animals to experience the negative welfare consequences that have been identified in the present Scientific Opinion ('restriction of movement', 'soft tissue and integument damage', etc.). These key parameters defining the minimal enclosure are defined from a bird welfare point of view.

In order to reply to the Specific ToRs in this Scientific Opinion, the description of the ABMs, preventive, corrective and mitigative measures provided in the sections of the general ToRs were used and synthesised in a narrative text. The following specific scenarios were considered:

1) The welfare of fast-growing chickens in barns and the risks associated:
    a) with air and floor temperature: this specific scenario has been interpreted as defining the minimal conditions to ensure in the barn upon the placement of day-old chicks,
    b) access to feed and water: this scenario will cover the access to feed and water of day-old chick at placement on farm and the access to feed and water during rearing, with the specific case of disabled animals with impaired health and growth or runts,
    c) space allowance: this scenario will cover the impact of space allowance on broilers chicken welfare,
    d) air quality: this scenario will cover the impact of air quality during rearing on birds' welfare.
2) The assessment of ABMs collected in slaughterhouses (such as footpad dermatitis (FPD)) to monitor the level of welfare on broiler farms: this scenario will propose valid indicators that can be used now, or in the future, for monitoring on farm welfare at slaughter.

3) The welfare of broiler breeders and the risks associated:

   a) with housing in (individual) cages: this scenario will synthesise the welfare consequences due to current cage housing of breeders and present available ABMs, as well as preventive, corrective and mitigative measures, if available.
   b) with the practice of routine mutilation (beak trimming, de-toeing, comb dubbing, de-clawing): this scenario will synthesise the welfare consequences due to current practices of mutilations to breeders and present available ABMs, as well as preventive, corrective and mitigative measures, if available.
   c) with feed restriction; this scenario will synthesise the welfare consequences due to current feed restriction in breeders and present usable ABMs, as well as preventive, corrective and mitigative measures, if available.

4) The welfare of day-old chick until they reach the rearing or breeding farms: the impact of hatchery conditions on chicks' welfare will be described in this Scientific Opinion. The impact of transport conditions is described elsewhere (EFSA AHAW Panel, 2022a).

As many hazards are considered in this Scientific Opinion and described at different places, the major recommendations to prevent or correct the hazards and to mitigate the WCs are included in Section 4.1 to summarise them.

In the context of this Scientific Opinion, chickens with a growth rate of less than 50 g/day are considered slower-growing and chickens with a growth rate of more than 50 g/day are considered fast growing.

To address the specific ToR 1c 'the welfare of fast-growing chickens housed in barn and the risk associated to the space allowance', a novel quantitative behavioural model was developed that accounted for nine essential broiler behaviours, in addition to the EKEs. Given the novelty of the behavioural model in animal welfare risk assessment it was decided to provide a detailed description of the model in the section of Methodology (Section 2.3.2.1).

In the opinion, we use stocking density, expressed in kg/m^2, as a proxy for the space allowance (m^2/animal) as usually stocking density is more used in fattening broiler chickens than space allowance.

In the context of this Scientific Opinion, when a certainty of 90–100% was attached to a conclusion this was not included between brackets.

2. Data and methodologies

2.1. Data from literature

Information contained in previous EFSA scientific outputs (SCAHAW, 2000; EFSA AHAW Panel, 2010; EFSA AHAW Panel, 2012), from the papers selected as relevant from the literature searches described in Section 2.3.3, and from additional scientific and grey literature identified by EFSA experts, was used for a narrative description, and subjected to a qualitative or (when possible) quantitative assessment to address the general and specific ToRs (see relevant sections of the assessment). Data on the relation between ABM(s) and the exposure variables of the specific ToRs were extracted and analysed.

2.2. Data obtained from the questionnaire to European Forum of Farm Animal Breeders (EFFAB)

Due to the lack of available information on broiler breeders, the working group prepared a questionnaire to obtain information on practices used in the EU that was filled in by EFFAB (see Appendix A). The information obtained was considered by the working group to perform the assessment. In addition, two EFFAB representatives answered follow-up questions in a hearing expert meeting (8 September 2021).

2.3. Methodologies

2.3.1. General ToRs

This Scientific Opinion follows the protocol detailed in the methodological guidance that was developed by the AHAW Panel to deal with all the mandates in the context of the farm to fork strategy revision (EFSA AHAW Panel, 2022b) and only those aspects that are specific for the welfare of day-old chicks, broiler chickens and broiler breeders are reported here.

The identification of welfare consequences followed the approach described in the methodology guidance (EFSA AHAW Panel, 2022b). From the list of the 33 welfare consequences described the methodological guidance EFSA AHAW Panel (2022b), the following 19 welfare consequences were identified as highly relevant for day-old chicks, broiler chickens and broiler breeders in the current Scientific Opinion:

1) Bone lesions
2) Cold stress
3) Handling stress
4) Heat stress
5) Gastro-enteric disorders
6) Group stress
7) Inability to perform comfort behaviour
8) Inability to avoid unwanted sexual behaviour
9) Inability to perform exploratory or foraging behaviour
10) Isolation stress
11) Locomotory disorders
12) Predation stress
13) Prolonged hunger
14) Prolonged thirst
15) Resting problems
16) Restriction of movement
17) Sensory under and/or overstimulation
18) Soft tissue lesions and integument damage
19) Umbilical disorders and hernia

The general ToRs requested EFSA to answer five assessment questions, which were divided into more specific sub-questions (EFSA AHAW Panel, 2022b). The approach to develop the sub-questions was based on using both evidence from the scientific literature and expert opinion.

The approach to identify relevant ABMs for these highly relevant welfare consequences, as well as hazards and preventive and corrective measures is described in the methodology guidance (EFSA AHAW Panel, 2022b).

In most of the cases, there was no quantitative data available about the sensitivity (Se) and specificity (Sp) of the different ABMs towards specific welfare consequences. Therefore, a qualitative judgement on the Se and Sp was provided by the experts. An ordered scale of categories was used to define the level of Se and Sp of the ABMs described in the Scientific Opinion as described below:

– High:

- High sensitivity: when the welfare consequence is present, the ABM will nearly always show it (e.g. when cold stress is present, the quasi-totality of day-old chicks will have a core temperature below 40°C); this would correspond, for example, to a Se range from 70% to 100%.
- High specificity: when the welfare consequence is absent, the ABM will be nearly always show this (e.g. in the absence of cold stress, chicks core temperature will be over 40°C); this would correspond, for example, to a Sp range from 70% to 100%.

– Moderate:

- Moderate sensitivity: when the welfare consequence is present, the ABM will often show this, but not in a certain proportion of cases (e.g. when cold stress is present, only a proportion of days-old chicks will perform distress calls); this would correspond, for example, to a Se range of 50–70%.
- Moderate specificity: when the welfare consequence is absent, the ABM will show this in most animals but not in all animals (e.g. if ability to perform exploratory or foraging behaviour is not limited, the walking/scratching/pecking expression can still be impacted due to other factors such as high animal stocking density or foot disease); this would correspond, for example, to a Sp range of 50–70%.

– Low:

- Low sensitivity: when the welfare consequence is present, the ABM may or may not show it (e.g. when breeders are experiencing prolonged hunger, they can show polydipsia in some case only), this would correspond, for example to a Se below 50%.
- Low specificity: when the welfare consequence is absent, the ABM will not indicate the absence in a substantial number of animals (e.g. in the absence of cold stress, chicks might perform distress calls for other reasons (e.g. overstimulation)); this would correspond, for example, to a Sp below 50%.

In this Scientific Opinion, a list of iceberg indicators was provided based on the ABMs listed for each of the described welfare consequences. 'Iceberg indicators' are indicators that can be used to obtain a quick overview on possible welfare problems, as they may reflect several welfare consequences in an integrative manner. Their presence implies that not only the animals that show them will experience these welfare consequences. They provide an overall assessment of welfare, just as the protruding tip of an iceberg signals its submerged bulk beneath the water's surface (FAWC, 2009; EFSA AHAW Panel, 2022a). For that reason and in the context of this opinion, the listed iceberg indicators should have the ability to effectively measure several welfare consequences at the same time.

2.3.2. Specific ToRs

2.3.2.1. Specific ToR 1c

Specific ToR 1c (see Section 1.1) was addressed using data from the literature and expert judgement. In addition, two structured EKEs were performed to assess the effect of space allowance on two ABMs: FPD and % time walking. The model used to perform the EKE is available in EFSA AHAW Panel (2022b). Out of the 4 EKE questions included in the methodological guidance (EFSA AHAW Panel, 2022b) the question on the coefficient of variation of the ABM in the population of animals not exposed to the hazard (with low stocking density) was not elicited for both EKEs. Instead, the coefficient of variation of the ABM for the highly exposed population was assumed to be 0.5 for the % time walking and 0.7 for FPD (see more details in the Appendix B); Furthermore, a fourth question was asked on the median value of the ABM on a population of broilers under an intermediate level of exposure to the stocking density. The evidence dossier with the elicitations results is available in Appendix B. In addition to address this specific ToR 1c, following the performance of the two abovementioned EKEs, a behavioural model was used to estimate the space allowance requirements on broilers based on the space needed to perform identified behavioural needs (see below).

Description of the behavioural model to estimate space allowance requirements on broilers

A quantitative modelling approach was applied to calculate the space allowance that would allow broiler chickens to express their behavioural needs for any improvement of welfare. The nine behaviours of fast-growing broilers selected were: 'standing', 'sitting', 'walking', 'foraging including scratching', 'dustbathing', 'preening', 'wing/leg stretching', 'wing flapping', 'drinking/eating'.

The selection of these behaviours was based on the WCs and ABMs described in this Scientific Opinion (see Section 3.4.2). The ABMs selected for the WC 'restriction of movement' were: 'locomotory behaviour' (walking) and 'wing flapping'. The ABMs selected for the WC 'inability to perform exploratory or foraging behaviour' is foraging defined by a complete behavioural sequence of walking, scratching and pecking. The ABMs 'dustbathing', 'preening', as well as 'wing and leg stretching' were chosen to reflect the WC 'inability to perform comfort behaviour'. In addition, behaviours standing and sitting were selected as these are highly prevalent in the case of 'locomotory disorders'. Resting behaviour was combined with passive sitting as this is the typical posture of resting birds and many studies did not differentiate between resting and sitting behaviours. As drinking and eating are essential to the birds, these behaviours were also integrated.

The space allowance (SA) is represented in Equation 1, where A_i represents the area required by an animal to perform a specific behaviour i and PB_i represents the proportion of each of the behavioural needs:

$$SA = \sum_{i=1\text{–}9}^{N} (A_i \times PB_i) \tag{1}$$

i = 1) standing, 2) sitting, 3) walking, 4) foraging including scratching, 5) dustbathing, 6) preening, 7) wing/leg stretching, 8) wing flapping, 9) drinking/eating.

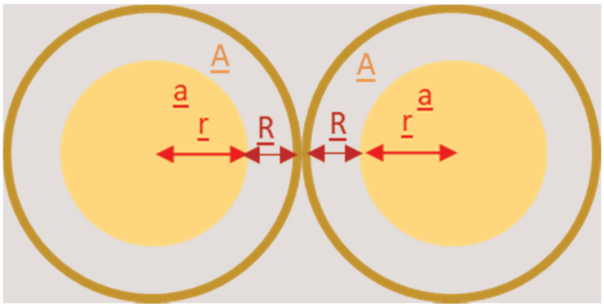
The area A is composed of three elements. First, it was assumed that broilers have the shape of a circle (yellow area 'a' in Figure 1). Second, the interindividual distances between broiler chickens were added for each behaviour. These interindividual distances take into account the distance needed for broilers to express their behavioural preferences in relation to the next neighbouring chicken. This distance depends on the specific behaviour expressed. The model includes a minimal distance 'D' between chickens performing the same behaviour. This interindividual distance is interpreted as an additional band of the radius around the circle (Equation 2).

$$R = \frac{D}{2} \tag{2}$$

The area A required to perform one specific behaviour is expressed in Equation 3 below.

$$A_i = \pi \times (r_i + R_i)^2 \tag{3}$$

$$i = 1\text{–}9$$



A = total space (area) including a = space covered, with r = being the radius of a broiler chicken and R being the radius added to reflect the interindividual distance D/2 since values for interindividual distances were divided by two birds.

Figure 1: The space occupied A by two broiler chickens depicted as two circles with the interindividual space

i = 1) standing, 2) sitting, 3) walking, 4) foraging including scratching, 5) dustbathing, 6) preening, 7) wing/leg stretching, 8) wing flapping, 9) drinking/eating.

Assuming, that the chickens will optimally and equally distribute in an area (Figure 2), we observe a small part, which is not covered by circles. This area is called ω and is calculated with Equation 4 (Steinhaus, 1999).

$$\omega = \frac{A}{0.9069} \tag{4}$$

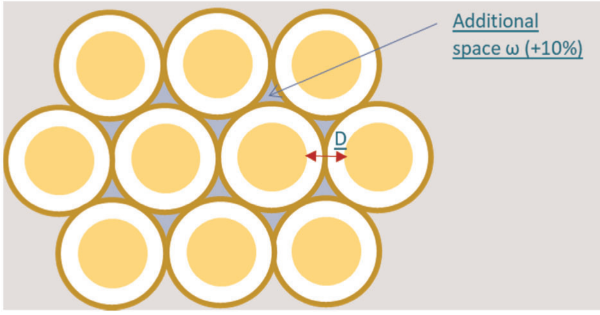


Figure 2: Depiction of the entire flock with the additional space ω between chickens (space covered by chicken plus interindividual distance)

Data collection

Data on the selected behaviours and space required (planimetric data) were extracted from the available literature.

The following parameters were extracted from the literature: the % of animals performing each behaviour, the space covered, interindividual distances and the weight of the birds. Only studies published after 2010 were considered to provide results with comparable hybrids as they are currently used commercially. During data extraction, special care was taken to ensure that values originate from the broilers' finishing phase, preferably between 32 and 42 days of life when the stocking density is higher in the barn. Space requirements were extracted from studies providing planimetric measures. Only studies that had used comparable definitions for the behaviours considered and where scan sampling was used for determining the parameters were included. Studies in which improved welfare conditions were applied were based on stocking densities lower than the maximum limit in the Council Directive 2007/43/EC[5] (stocking densities between 33 and 42 kg/m^2 are commonly applied). Studies from cage housing were excluded. Studies reporting the % of behaviours when enrichment was present were included.

Only data for the fast-growing hybrids were used from the studies. If different values were given over different trials, times of day, etc., these were averaged. The number of studies per behaviour is shown in Table 1.

The space required (in cm^2) by an individual broiler chicken performing each essential behaviour were extracted from the literature. Since no data were available for 'walking', it was assumed that for walking the broiler equals the double of the space required for standing to allow for free space for walking activity. Additional data from the space covered by laying hens (e.g. Question to EURCAW-Poultry-SFA on the space needed for a pullet at feeder, (EURCAW-Poultry-SFA, 2022)) were used. As these data were extracted from laying hen studies, a conversion factor was used to adjust the space covered by a broiler. For this purpose, the mean space covered by a broiler standing, sitting/resting was calculated as for these behaviours the most data points were available (n = 4). These values were compared with the space covered for the laying hens. Conversion factors were 0.94 for standing and 0.95 for sitting/resting (broiler/laying hen). The mean of these factors was calculated and equals 0.945. In other words, a broiler occupies 0.945 the space of a laying hen. The space required to perform the behaviours for the laying hens were recalculated for the remaining behaviours to be used for broilers (see Appendix C for details).

Finally, the average weight of a broiler chicken was extracted from the same references and an average value was calculated from these data points. The weight used for broilers in the model equals 2.7 kg (see Appendix C for details).

Labelling the nine behavioural needs of broiler chickens

Data in relation to the proportion of animals performing selected behaviours in improved conditions and the space needed to express these behaviours were extracted for two categories of behaviours and labelled as 'stationary' and 'active' behaviours: These labels were mainly assigned to classify the behaviours according to the amount of space needed. Behaviours that require more space and should be promoted were labelled as active and the ones that require less space were labelled as stationary.

- the mainly inactive behavioural, i.e. stationary behaviours are: standing, sitting/resting and drinking/eating;
- the behaviours that are associated with locomotory behaviour supporting animal welfare, i.e. active behaviours are: (1) walking, (2) foraging including scratching, (3) dustbathing, (4) preening, (5) wing/leg stretching, and (6) wing flapping.

Table 1: Nine selected essential behaviours of broilers, their labels and the number of studies used in the behavioural stocking density model for broiler chickens for the proportion of behaviour and surface required

Behaviour	Label	Number of studies used for extraction 'the proportion of behaviour'	Number of studies used for extraction 'surface required'
Standing	Stationary	11	4
Sitting/Resting	Stationary	12	4
Walking	Active	9	0[(a)]
Foraging including scratching	Active	9	2
Dustbathing	Active	8	2
Preening	Active	9	2
Wing/Leg stretching	Active	7	2
Wing flapping	Active	4	1
Drinking/Eating	Stationary	12	2

(a): No data was available on the space required for walking and it was assumed to be double the space standing.

The total number of extracted values/data points (N) as well as their minimum, median, mean and maximum of proportion of birds showing the behaviours were calculated. In addition, so-called stabilised values were calculated to adjust for the variability and small number of the available data of some specific behaviours (e.g. wing flapping). The stabilised values are based on the mean of the lowest and highest two values for the stabilised minimum and maximum, respectively.

Standardisation of the proportion of the behaviours

The proportion of behaviours found did not add up to 100% per reference due to (i) sum of behaviours in ethogram did not sum up to 100% in the original study already, and/or (ii) not all data were extracted from the original study, only those that referred to the selected 9 behavioural needs. Therefore, these proportions were standardised to a total of 100%. This standardisation step was conducted to create a behaviour profile that corresponds to an 'ideal behaviour profile' for fast-growing broiler. This standardisation also contributes to the understanding of the ideal ethogram profile of a broiler depicted (see Appendix C for details).

Calculation of median, mean, optimum model, stabilised optimum model of proportion of birds showing the selected behaviours

As descriptive statistics, the total number of extracted values/data points (N) as well as their minimum, median, mean and maximum of the proportion of broiler chickens showing the behaviours were calculated. In addition, so-called stabilised values were calculated to adjust for the variability and small sample size of the available data of some specific behaviours (e.g. wing flapping see Table 1). The stabilised values are based on the mean of the lowest and highest two values for the stabilised minimum and maximum, respectively.

The values were further processed by including the previously chosen label as active or stationary for four different models:

a) median model (median of the proportion of birds performing all the selected behaviours)
b) mean model (mean of the proportion of birds performing all selected behaviours)
c) optimum model (median of the proportion of birds performing the stationary and maximum for the active behaviours)
d) stabilised optimum model (median of the proportion of birds performing stationary and median of the two highest values for active behaviours, i.e. stabilised maximum)

The mean is the most common approach used in data analysis. Using the median is more appropriate when the data range is large and the data points limited and non-parametric. For the optimum model, the maximum value of the proportion of birds performing the positive selected behaviours is implemented reflecting that, e.g. the highest proportion of broilers reported in the literature show a positive behaviour. As the optimum model relies on a single maximum value, another approach was followed to produce a more robust model, the stabilised optimum, by integrating not only the maximum but also the median of the two highest values of the proportion of birds performing the positive behaviours. The stabilised optimum accounts for the variability within the selected behaviours that was sometimes high, by buffering it with the median. Implementing four mathematical approaches allows more confidence in the outcomes, reflecting the robustness of the model in general.

Sensitivity analysis

A sensitivity analysis was conducted to identify input parameters with highest contributions to the overall uncertainty of the total space requirement per broiler (model output). To do so uncertainty distributions of the lowest, median and highest value of the proportion of birds, space and interindividual distance required for the nine behaviours were inserted in the model. For constants a theoretical uncertainty of $\pm$ 10% was assumed. A linear regression was used to identify the relative contributions of each parameter to the total uncertainty (expressed as R^2 of the regression model).

Limitations of the behavioural model

Not all definitions of the different behaviour categories are the same across the 17 studies used for data extraction. As there is no standardised and uniformly used ethogram, a minimal range of deviations was allowed, as long as the core of the behaviour was covered. For example, the data point on walking was only included if exclusively walking was measured. For wing and leg stretching, however, individual or summed individual values were used.

The extracted data on behaviours did not add up to 100% in each study, which was due to different reasons, e.g. because only a subset was extracted from the study that fit the predefined categories/definitions of the selected behaviours. In most studies, only specific behaviours and not complete time budgets/ethograms were produced. In addition, the method of scan sampling could differ regarding time of the day, frequency and interval, introducing additional variability into the dataset.

The model might not reflect the circadian rhythm of the birds or social facilitated behaviour, e.g. dust bathing which is preferably shown by several birds simultaneously. The modelling approach does not allow every bird to perform every behaviour at the same time but reflects the proportions of birds showing the range of behaviours selected at a certain time.

The behaviours with a high space requirement appear to drive the model outcome more than behaviours with low space requirements. However, since these behaviours (e.g. wing flapping and foraging) are expressed at low frequency (7.1% and 8.7%, respectively), their impact on the final outcome is relatively low.

Underlying assumptions of the behavioural model

The label ‘negative’ was not used, as all the behaviours shown are part of the animals’ natural repertoire. The distinction between stationary and active is based on the assumption that certain behaviours should be further promoted for good animal welfare.

A complete ethogram was not compiled, as the primary aim was to present the predominant behavioural categories that are directly related to animal welfare. Rather, the definitions that relate the behaviours to the space allowance data and the extracted categories should be kept the same and applied. Therefore, various studies and data points that did not match the definitions were omitted, e.g. when locomotion was walking and hopping, or foraging as pure pecking without scratching. The definitions on which the data are based should be congruent with those on which there are data on ‘space covered’.

2.3.2.2. Specific ToR 2

This specific ToR considers broilers that will be sent to the slaughterhouse. It aims at identifying a list of ABMs that can be assessed and collected at slaughter to monitor the welfare condition on farm of a certain population in a flock, farm or region/country. Preferably, these should be ‘iceberg indicators’: ABMs that help to identify more than one welfare consequence (EFSA AHAW Panel, 2022c).

A list of ABMs initially considered potentially relevant for measurement at slaughter in broilers was identified by EFSA experts on the basis of existing literature (Welfare Quality®, 2009; EFSA AHAW Panel, 2012) and further discussed during the EFSA scientific National Contact Points (NCPs) Network annual meeting (EFSA, 2021).

Additional ABMs were added to this list by the EFSA working group based on expert opinion. This list was then subjected to: (i) screening of ABMs and; (ii) selection of ABMs.

The full methodology is described in Appendix D.

2.3.2.3. Specific ToRs 3 and 4

Specific ToRs 3 and ToR 4 were addressed using data from the scientific literature and expert judgement.

2.3.3. Literature searches

2.3.3.1. General ToRs

Background information for description of broiler categories and husbandry systems, welfare consequences, ABMs, hazards and preventive, corrective and mitigative measures (general ToRs) is reported in previous EFSA Scientific outputs and External reports prepared for EFSA with updated literature assessing diverse aspects of broiler welfare (EFSA AHAW Panel, 2010; de Jong et al., 2012a).

This information was complemented by the results of extensive literature searches (ELSs) that were carried out to retrieve additional information for the General ToRs, and by any additional relevant publication in a reference list of relevant review articles and key reports or proposed by EFSA experts. All relevant publications were included in an EndNote Library.

2.3.3.2. Specific ToRs

ELSs were carried out to identify scientific evidence reporting welfare implications and associated ABM(s) with strong relationship to each of the exposure variables. Restrictions were applied in relation to the date of publication, considering preferably those records published after the latest EFSA Scientific output on the topic (EFSA AHAW Panel, 2010; de Jong et al., 2012a).

The searches were saved in Web of Science and relevant results (records) appearing at a later stage were screened and added to the pool of papers available to the experts. Relevant publications retrieved from the bibliographic database were exported to EndNote ×7 together with the metadata (e.g. title, authors, abstract). In addition, review articles and key reports were checked for further articles, and EFSA experts were invited to propose any additional publications they were aware of, until the information of the exposure variable was considered sufficient to undertake the assessment. If needed, relevant publications published before previous EFSA Scientific outputs were also considered.

2.3.3.3. Uncertainty assessment

The AHAW Panel agreed to assess the uncertainty related to the data inputs and the methodology employed to identify welfare consequences, ABMs and related hazards by first describing the potential sources of uncertainty affecting the assessment.

The impact of these uncertainties on the assessment of the general ToRs of this Scientific Opinion was assessed collectively by all the WG members in plenum following the procedure described in the EFSA guidance on uncertainty analysis in scientific assessments (EFSA Scientific Committee, 2018a, 2018b) for case-specific assessments with some modifications.

For the general ToRs, EFSA experts agreed to limit the assessment to the quantification of the overall impact of the sources of uncertainty on the summary conclusions developed in Section 4. Experts were asked to provide their individual judgement on the certainty they had for each conclusion according to three predefined agreed probability ranges (> 50–100%; 66–100%, 90–100%), derived from the approximate probability scale from the guidance on uncertainty (EFSA, 2019). Individual answers were then subjected to group discussion during which experts had the opportunity to explain the rationale behind their judgement, and a consensus on which category better reflected the overall uncertainty was reached. A qualitative translation of this consensus category was also derived (e.g. 'more likely than not' for an uncertainty of > 50–100%, Table 2).

For the specific ToRs addressed through EKEs, a more quantitative approach was used, and the uncertainty was assessed as part of the exercise (as described in EFSA AHAW Panel (2022b)). For the exposure variables considered for which EKEs were not possible or not considered relevant, the uncertainty was assessed following the procedure used for the general ToRs.

Table 2: Three probability ranges used to express agreed (consensus) uncertainty around conclusions (adapted from EFSA, 2019)

Quantitative assessment	**Probability range**		
	> 50–100%	**66–100%**	**90–100%**
Qualitative translation	More likely than not	From likely to almost certain	From very likely to almost certain

In the conclusions, when certainty was from 90 to 100%, it is not indicated in the corresponding text. Uncertainty is specified (into bracket at the end of each conclusion) only in the case where certainty is below 90%.

3. Assessment

3.1. Broiler production in the European Union

Broilers represent the major share of poultry meat production in Europe (83%) and globally (DG Agri, 2022).

Intensive broiler production in EU 27 is characterised by very large holdings, indoor rearing, high stocking densities and fast growth rates. This production model accounts for around 90% of the broiler production in the EU. The main EU producing countries tend to apply stocking densities between 33 and 42 kg/m^2. According to Eurostat, 891.4 million broilers were produced on more than two million farms across the EU in 2013.

During the second half of the 20th century, the growth rate of broiler chickens quadrupled, mainly as a result of genetic selection (Zuidhof et al., 2014). The main three commercial broiler breeds are Cobb, Hubbard and Ross. Slower growing broilers (with slaughter age ranging from 70 to 81 days minimum) have gained interest in many European countries in recent years, while they have long been present in other countries (e.g. Label rouge, Beter leven).

In the European Union as well as in other industrialised regions, broilers are produced in vertically integrated production systems/chains. The number and date of chicks hatched and delivered to the farms and from farms to the slaughterhouses follow a strict time schedule. This allows optimum utilisation of facilities at the hatchery, farm, slaughterhouse and transport level. Conventional commercial broilers in the EU are usually kept in flocks of 10,000–40,000 individuals. However, there is no information available on the distribution of broilers among the different husbandry systems in the EU.

The legislative requirements from the Council Directive 2007/43/EC[5] laying down minimum rules for the protection of chickens kept for meat production and are summarised in Table 3.

Table 3: Requirements applicable to broiler chickens, meaning animals of the species *Gallus gallus* kept for meat production in three different stocking densities (33 kg/m^2, 33–39 kg/m^2, 39–42 kg/m^2) in Council Directive 2007/43/EC[5]

		Stocking density		
		33 kg/m^2	**< 33–39 kg/m^2**	**< 39–42 kg/m^2**
Certificates	Detention an official certificate on animal welfare training or proven experience on animal welfare	X	X	X
Inspections	Inspection of animals at least twice a day	X	X	X
Register	Retention of a register of birds' mortality at least for 3 years	X	X	X
Drinkers	Drinkers shall be positioned and maintained in such a way that spillage is minimised	X	X	X
Feeding	Feed shall be either continuously available or be meal fed and must not be withdrawn from chickens more than 12 h before the expected slaughter time	X	X	X
Litter	All chickens shall have permanent access to litter which is dry and friable on the surface	X	X	X

		Stocking density		
		33 kg/m^2	< 33–39 kg/m^2	< 39–42 kg/m^2
Ventilation and heating	Ventilation shall be sufficient to avoid overheating and, where necessary, in combination with heating systems to remove excessive moisture	X	X	X
Noise	The sound level shall be minimised. Ventilation fans, feeding machinery or other equipment shall be constructed, placed, operated and maintained in such a way that they cause the least possible amount of noise	X	X	X
Light intensity	All buildings shall have lighting with an intensity of at least 20 lux during the lighting periods, measured at bird eye level and illuminating at least 80% of the useable area. A temporary reduction in the lighting level may be allowed when necessary following veterinary advice	X	X	X
Light – periods of darkness	Within seven days from the time when the chickens are placed in the building and until three days before the foreseen time of slaughter, the lighting must follow a 24-h rhythm and include periods of darkness lasting at least 6 h in total, with at least one uninterrupted period of darkness of at least 4 h, excluding dimming periods	X	X	X
NH_3 concentration[(a)]	NH_3 concentration $\leq$ 20 ppm on instant measurement		X	X
CO_2 concentration[(a)]	CO_2 concentration $\leq$ 3,000 ppm on instant measurement		X	X
External/internal temperature[(a)]	Internal temperature $\leq$ to the external temperature + 3°C when the exterior temperature in the shade is > 30°C		X	X
Relative Humidity[(a)]	Relative humidity $\leq$ 70% over 48 h when the external temperature is < 10°C		X	X
Daily mortality[(a)]	Cumulative daily mortality rate < 1% + 0.06% × N (N = age expressed in days taken to arrival to the abattoir) There is a possibility of a derogation if an explanation is provided			X

(a): These are additional criteria to allow owners to have higher stocking rates than the maximum allowed according to Directive EC 2207/43.

3.2. Production cycles of broilers and respective animal categories

3.2.1. Day-old chicks hatched in hatcheries or on-farm

Traditionally, and by far the most common practice, broiler chicks hatch in hatcheries after 18 days of incubation followed by approximately 3 days in a hatching chamber. However, during recent years, hatching directly on-farm has been developed as an alternative, involving placement of the eggs after 18 days of incubation (in commercial hatcheries) in broiler barns where the climate condition has been adjusted to be suitable for the hatching process. Several on-farm hatching systems have been developed in recent years, differing in the degree of equipment and labour needed (van de Ven et al., 2009; Diervoeding, 2014; de Jong and Gunnink, 2019; Jessen et al., 2021a).

The range of procedures that the chicks go through post-hatch depends on the hatching method. Obviously, only hatchery chicks are exposed to crating in boxes and transportation. However, also the handling of the chicks for other procedures, such as sorting, vaccination and in some cases sexing, is performed differently depending on the hatching method (Jessen et al., 2021a).

3.2.2. Broiler chickens for meat production

If not hatched on farm, chicks are usually transported from the hatchery to the rearing facility. Management guides inform about the special needs and performance data of broilers placed on farm. Flocks size ranges from 10,000 to 40,000 on average. Conventional production cycles of fast-growing chickens differ slightly in their time period ranging typically between 28 and 30 days (short, ca. 1,500 g), 32–35 days (intermediate, ca. 2,000 g) and 38–42 days (long production cycle, ca. 2,500 g) of life following an all-in-all-out system. Slower-growing broilers and organic production might be kept until 12 weeks of age (WOA) on average, although some organic broilers are slaughtered as young as at 8 WOA. Also splitting methods might be applied, which means that within the rearing period the flock is partly reduced allowing the remaining birds to gain more weight with an increased space allowance, a procedure called 'thinning'.

3.2.3. Broiler breeders

Broiler breeders are the parent and earlier generations (e.g. grandparents, great grandparents) of the commercially used broilers (broiler chickens for meat production). Broiler breeders are kept to maintain production of fertilised eggs from which the broilers hatch, as well as earlier generations including the pure lines in which selection for desirable traits is performed. The production cycle of broiler breeders lasts 64 weeks and goes sometimes up to 70 weeks. At 24 weeks of age, laying production picks up at about 5% and reaches the peak of 85% at 29 WOA. The average female broiler breeder lays 183 eggs in total during the production cycle, which yields 175 hatching eggs. A second production cycle after moulting is not common, but possible (Attia et al., 1994).

Broiler breeding consists of selecting animals of pure lines with a blend of various desired characteristics, mating the selected animals with the selected birds of another pure line, rearing and crossing the F1's with other F1's, and continuing for more generations until the male and the female broiler parent lines, respectively, are mated to produce the commercial broiler. At every generation, the number of individuals is multiplied. For example, a group of one male and 10 females in one of the male great grandparent populations can contribute 25% of the genetic material of approximately 87.5 million broilers in 4–5 years (EFSA AHAW Panel, 2010). That said, birds of the pure lines are very valuable. Breeding programmes are developed to respond to the needs of farmers and the market. To ensure that the traits needed for production are selected, birds are placed individually in a cage to collect the individual data required (questionnaire to EFFAB, see Appendix A).

The selection goals of efficient and fast growth rates and gain of breast meat in broilers are negatively correlated with fertility in broiler breeders (Siegel and Dunnington, 1988). Ongoing genetic gains in broiler growth rates and feed efficiency require a constant adaptation in management including severe feed restriction while ensuring enough nutrients in the breeders, called the broiler breeder paradox (Decuypere et al., 2006).

As broiler breeders lack self-control of feed intake, the amount of feed must be restricted at the right level in both sexes to avoid severe health, welfare and production problems due to obesity (Arrazola and Torrey, 2021). For that reason, males and females are reared separately until sexual maturity. When both sexes are mature, males and females are put together for mating.

Male fertility declines with age. Restoring male fertility beyond 40 WOA can be achieved by either spiking (exchange of old males by young males) or administration of testosterone to old males (Ordas et al., 2015). Injections of testosterone are only feasible for caged males and are stressful.

In pure lines and grandparent stock, some animals are kept in single or collective cages and are artificially inseminated. In the European Union, parent stock is kept in loose housing systems on litter.

3.3. Husbandry systems per animal categories

Table 4 displays the three categories of birds and the husbandry systems in which they are usually kept in. A more detailed description of the 10 husbandry systems is included in Sections from 3.3.1 to 3.3.10. All systems are indoor unless otherwise stated.

Table 4: Husbandry systems per category of bird

Husbandry system	Day-old chicks	Chicken for meat production	Broiler breeders
Hatched in hatchery	x		
Hatched on farm	x		
Floor systems		x	
Floor systems with covered veranda		x	
Floor systems with outdoor free range		x	
Mobile systems with outdoor free range		x	

Husbandry system	Day-old chicks	Chicken for meat production	Broiler breeders
Individual unfurnished cages			x
Floor systems with raised slats			x
Collective cages furnished or not			x
Floor system with multi-tier			x

3.3.1. Day-old chicks hatched in hatchery

Traditionally, broiler chicks hatch in a hatchery. After 18 days of incubation, eggs are usually transferred to hatching trays in a hatching chamber. The temperature and humidity in the hatching chambers are regulated to provide optimal conditions for hatching (Welfare Quality®, 2009; Mench et al., 2021). Hatching time is spread across a 'hatch-window', typically 24–48 h (Careghi et al., 2005; Willemsen et al., 2010b; Tong et al., 2015a), which is dependent on, e.g. age of the parent stock, egg handling, egg storage time and the incubation conditions (Decuypere et al., 2001). This may result in an age difference of chickens of a day or more. During the hatching period, i.e. embryonic days 18–21, chicks are exposed to disinfection, high levels of dust, pathogens and noise and often continuous darkness (Mitchell and Waltman, 2003; Archer and Mench, 2014). After hatching, chicks are taken from the hatching chamber in trays and go through a number of hatchery procedures, including separating chicks from egg shells and debris, sorting out second-grade chicks, vaccination, eventually sexing (usually only slower-growing hybrids and breeders), counting and crating which usually takes 2–4 h (Bergoug et al., 2013a; Hedlund et al., 2019). Broiler breeder chicks can also be subjected to mutilations (e.g. beak trimming, toe clipping) in the hatchery (see broiler breeder Sections 3.3.8–3.3.10). Separation and further processing are usually done by automated systems and involves rollers and high-speed conveyor belts that transport chicks through the hatchery. Following the hatchery procedures, broiler chicks are subjected to a waiting period, most often without access to feed and water, before they are loaded on a lorry and transported to the broiler farm where they are unloaded and placed in the barn. Transport is a significant stressor for day-old chicks (Bergoug et al., 2013a); see EFSA AHAW Panel (2022a).

Any unhatched chicks are destructed upon removal of the trays from the hatching chambers and separating the chicks from egg shells (Butterworth et al., 2021). Killing methods for day-old chicks are described in EFSA AHAW Panel (2019).

With the traditional method of hatching, chicks do not receive feed and water until placement on the broiler farm, unless they are sent for long-term road or air transport during which nutritive gel should be provided (see EFSA AHAW Panel (2022a)). In addition, time spent in the hatcher after hatching, time needed for the hatchery procedures and duration of transport add to the deprivation period, which all in all may last up to 72 h post-hatch (Willemsen et al., 2010b), the maximum duration of time a newly hatched chick is currently allowed to be deprived from feed and water according to the European legislation (Council Regulation (EC) No 1/2005[6]). However, in many countries, the deprivation period is considerably shorter than 72 h, mainly because transport time is limited due to short distances between hatcheries and farms.

To prevent the post-hatch feed and water deprivation of chicks, systems have been developed within recent years where the chicks are provided with feed and water in the hatchery immediately post-hatch (e.g. HatchCare and SmartStartTM). In these systems, feed and water or semi-moist feed and light are provided in the hatcher (Van der Pol et al., 2015; Souza da Silva et al., 2021).

3.3.2. Day-old chicks hatched on farm

Several on-farm hatching systems for broiler chickens have been developed. It is common for the systems that eggs are transported to the rearing farm on embryonic day 18 of incubation for the chicks to hatch on farm. Some systems require investment and installation of new housing equipment, whereas others are more basic but also more labour-intensive. These systems require adjusted management from the farmer compared to hatchery hatching, such as carefully monitoring environmental and egg temperature during the hatching process. The on-farm hatching systems described below are Patio™, X-Treck®, Home Hatching™, One2Born® and NestBorn®, but more systems can exist in practice, so the systems described below should be regarded as illustrative examples.

Patio™

Patio™ (©Vencomatic Group) is a fully equipped housing system installed in a barn where eggs are placed for hatching, and the broiler chickens are kept in the system until slaughter (Figure 3) (van de Ven et al., 2009). The system comes in cells, each consisting of two rows, both stacked in six identical tiers, with a separating corridor and a corridor on the outer side of each row. A system of conveyor belts at the bottom of each tier supplies the broiler chickens with feed, water and litter. Each belt is placed underneath a transport system for the setter trays in which the chicks hatch. When starting to move after hatching, the newly hatched chicks drop from the setter trays to the belt where they can access feed and water. Climate is automatically controlled in each layer using preconditioned air.

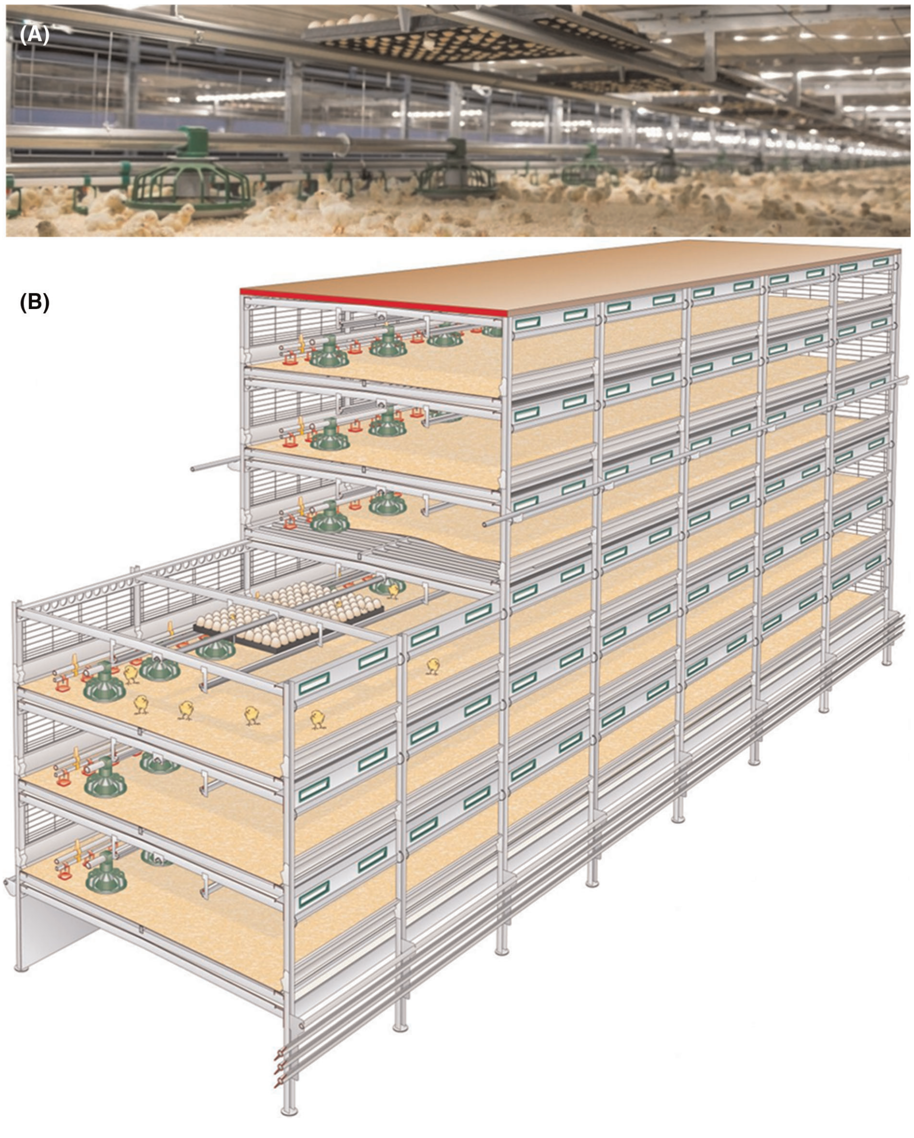


Figure 3: The Patio™ on-farm hatching system – (A) photo and (B) schematic drawing ©Vencomatic Group

X-Treck®

The X-Treck® system consists of an elevated rail system installed in a barn (Figure 4) (de Jong et al., 2019, 2020; Souza da Silva et al., 2021). It is suspended freely in the air where the setter trays with the incubated eggs are placed (Figure 4B). This is done either manually or by use of an automatic setter tray transport system, reducing manual labour. Temperature and airflow are partly controlled by raising or lowering the system. The adjustment of the height may be accomplished by use of either a manual or an electrical winch. When hatching draws near, the system is lowered such that either the newly hatched chicks drop directly onto the littered floor, where feed and water is available, or the drop to the floor goes through an In-Cradle system with a synthetic surface positioned underneath the setter trays.

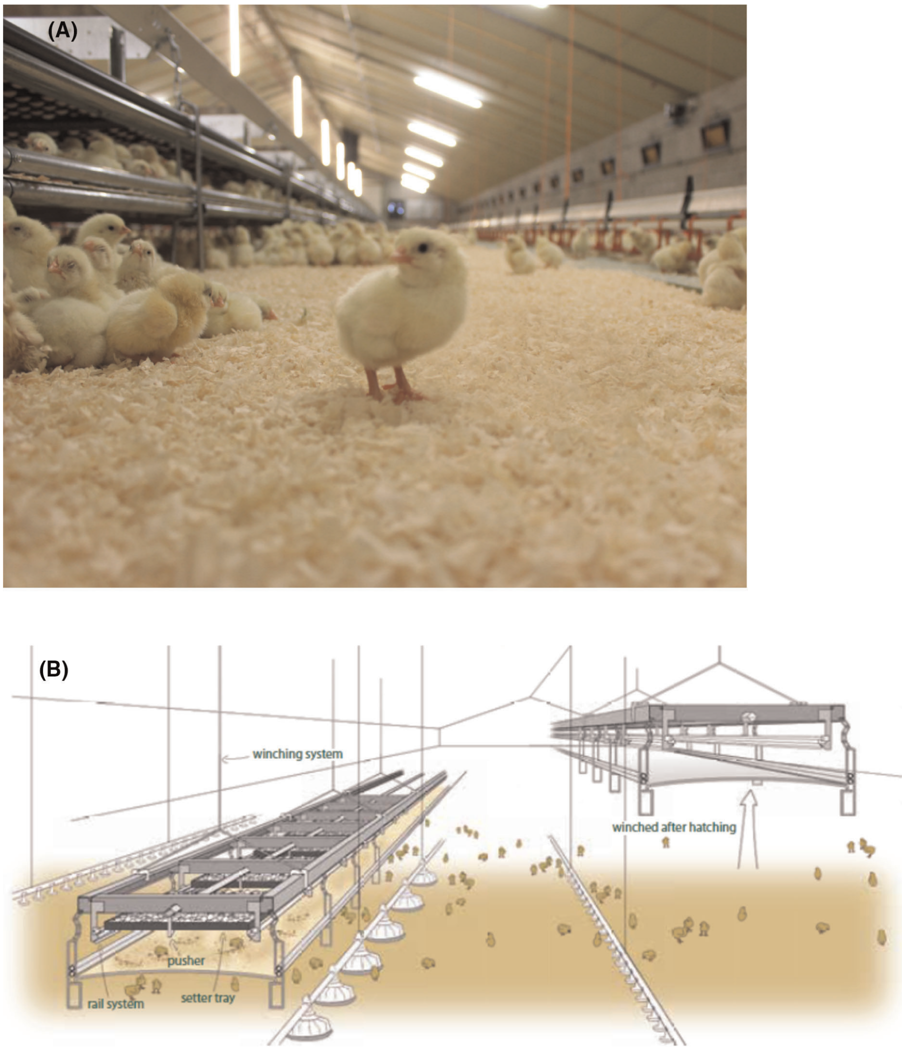


Figure 4: The X-Treck® on-farm hatching system – (A) photo and (B) schematic drawing © Vencomatic Group

Home Hatching™

In the Home Hatching™ system, incubated eggs are placed in setter tray racks in a barn from where the chicks, after hatching, drop to the littered floor to access feed and water (Figure 5). Infrared heaters are used to maintain correct temperature, heating the eggs and the litter below the racks, which facilitates the drying process of the chicks, once they have emerged from the eggs. Originally, the system was meant to stay in the barn until slaughter, raised to the ceiling with a winch after completed hatching. However, it has later been refined into a more lightweight system capable of collapsing by means of a folding mechanism such that it can be removed from the barn after each completed hatching of a batch (Diervoeding, 2014).

Figure 5: The Home Hatching™ system for on-farm hatching where eggs are placed in racks. (A) the hatching process (© Coppens Diervoeding) and the barn before placement of setter egg trays – notice the infrared heaters above the racks (© Peda BV)

One2Born®

In the One2Born® on-farm hatching system, the incubated eggs are placed in so-called hatchholders (Figure 6; One2Born®, n.d.) (Jessen et al., 2021a). The hatchholders resemble traditional egg trays, but they hold 50 eggs each and are designed, so a natural airflow is facilitated. The hatchholders containing the incubated eggs are manually placed directly in the litter in the preheated barn, requiring no large-scale investments. After hatching, the recyclable hatchholders are collected and either removed and discarded or they are used as environmental enrichment. If the latter approach is used, then the hatchholders stay in the barn, stacked in approximately 50 cm high piles, for the broiler to use them either as pecking objects or elevated resting places.

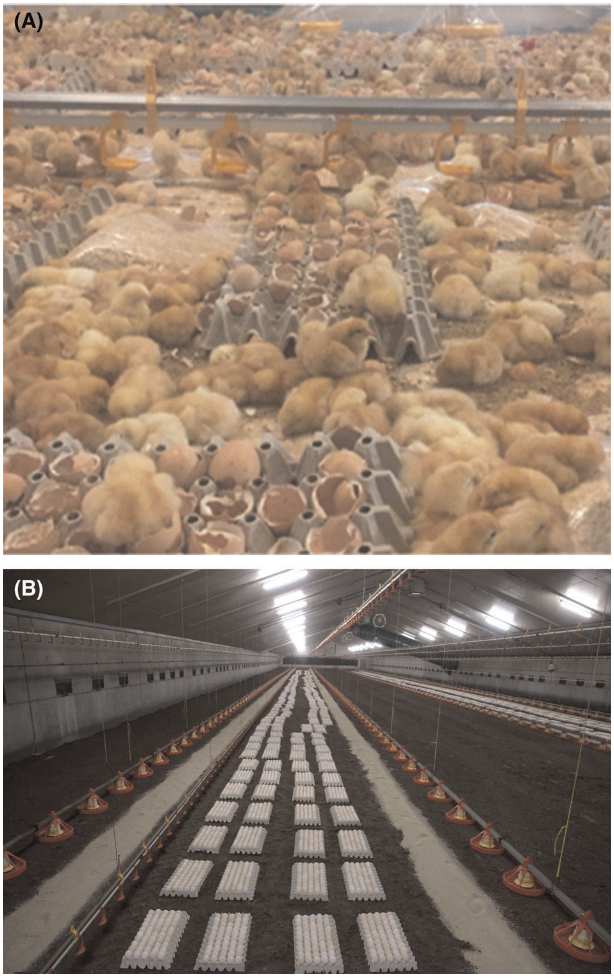


Figure 6: The One2Born® system for on-farm hatching where eggs are placed in hatchholders directly in the litter. (A) the hatching process (Photo credit: Anja Brinch Riber) and (B) the barn after placement of hatchholders (© One2Born)

NestBorn®

NestBorn® is an on-farm hatching system where the incubated eggs are placed directly in a 5–6 cm bed of litter in a barn, requiring no specific installations or investments in the broiler house (Figure 7; NestBorn®, n.d.). Automation may be gained at different levels; a machine may be used for swift placement of the eggs (Figure 7B), and for ease of management some of the eggs may be connected to a device that measures the temperature and relative humidity of the environment and eggshell in real time, allowing for optimal adjustment of the hatching environment (Graumans, 2018).

Figure 7: The NestBorn® on-farm hatching method where eggs are placed directly in the litter – (A) the hatching process (NestBorn®, Photo Credit: Ceres Media, Netherlands) and (B) placement of eggs using a machine specifically designed for the process (NestBorn®, Photo Credit: HFHC)

3.3.3. Chickens for meat production kept on floor systems (indoor)

Broiler chickens in indoor floor housing systems are mostly kept in large-scale buildings that usually do not have structural elements other than (automated) feed and water lines (Figure 8). The floor is usually made of concrete (ground soil floor may also exist in old buildings) and fully covered with substrate. Different types of substrates are used, of which wood shavings, peat and (chopped or pelleted) straw are most common. Sometimes young chickens are first acclimatised to their new environment in so-called chick (brooding) rings. These also ensure that the distance of the chicks to the feed and water lines is not too long. For young chickens, chick paper or cardboard egg trays are laid out on the floor area, filled with feed, to promote feed intake during the first days of life. When the birds walk over the chick paper, feed particles move and trigger the chicks to peck. The use of chick paper also facilitates the differentiation of feed from litter. The water lines consist of open round or nipple drinkers, which are well accepted by the chicks. This is due to the reflection of the metal and the water drops at the nipples. Nipple drinkers are usually positioned above the birds' heads to avoid spillage, although broilers prefer lower-positioned drinkers so that they do not have to stretch out to drink (Houldcroft et al., 2008). Feed is usually offered in round troughs by automated feeder systems. As the chickens cannot regulate their own body temperature in the first days, the house should be heated sufficiently before arrival and in the first weeks. Environmental temperature should be 28–30°C at placement at 60–70% humidity, as both are strongly correlated, other (higher) temperatures might be applicable in case of (lower) humidity. The thermal need might also depend on the age of the parental stock, with 1–2°C more for chicks of young flocks. In case of using spot brooding, 32°C should be provided at the edge of the brooders (Aviagen, 2018a). Different types of heaters are used, sometimes in combination with underfloor heating, which can be regulated according to the temperature requirements of the birds (Thiele, 2007). Local radiant heaters are also used, although dark brooders that have shown to increase broiler welfare are seen very seldom (Sirovnik and Riber, 2022). If dark brooders are used as the heat source, sufficient brooder space per chick needs to be provided. In a study of fast-growing broilers kept at a stocking density of 20 kg/m^2, Forslind et al. (2022) reported that at a brooder space allowance of 120 cm^2/chick, all chicks fitted under the brooders until the brooders were removed at 21 days of age. It is known from layer chicks (Isa Warren) that a brooder space allowance of 54 cm^2 per chick is sufficient (Riber and Guzman, 2016; Riber and Guzman, 2017). Further studies are needed to examine if the brooder space allowance can be reduced for broilers, while also taking the growth rate into consideration. A temperature schedule is applied where the environmental temperature in the house or under the dark brooders is gradually decreased until 18–20°C at the end of the rearing period following hybrid-specific management guides. If dark brooders are used as the only heat source, the environmental temperature in the house can be kept at 20°C from placement of the chicks (Forslind et al., 2022).

Light supply is usually permanent in the first days and the humidity is high (60–70%, Aviagen (2018a)). During rearing, the light duration is reduced so that the birds have a short night phase. Intermittent light programmes can also be used. At least 6 h of darkness per 24 h should be provided, of which 4 h should be uninterrupted according to EU legislation, from day 7 of age until 3 days before slaughter (Directive 2007/43/EC[5]). A minimum light intensity of 20 lux at bird height should be applied for 80% of the floor area (Directive 2007/43/EC[5]). Daylight access is not common although in some countries the number of houses with roof or wall windows is increasing (see Figure 8B), and this results in more varying and higher light intensities. Windows can be equipped with shutters to regulate light intensity.

The most important component of the indoor floor system affecting welfare is the litter and its management. Since the animals are in direct contact with the litter for the entire rearing period and there is usually no manure removal during a production cycle, regular re-littering would be of high importance. The litter should allow the animal to carry out natural behaviour (e.g. dustbathing, foraging and exploration) until the end of the rearing period. According to Directive 2007/43/EC[5] chickens should have permanent access to dry and friable substrate (litter) on the floor. Several techniques to reach good litter quality are being developed to provide birds automatically with enrichment substrates as well as new bedding material (automated dispensers), although they are not seen often in practice. Often, these automatic systems are hung under the ceiling and let enrichment material or bedding trickle into the barn at regular intervals to encourage the animals' natural exploration and foraging behaviour as demonstrated by (Giersberg et al., 2019) for layers. Management guides of the breeding companies provide detailed information on the required management for each hybrid such as light intensity, distribution, duration, feed and water supply, health and climate (temperature, humidity, ventilation) (e.g. Aviagen, 2018a; Cobb, 2021; Hubbard, 2022).

Additional modifications or resources can be present, according to, e.g. quality assurance schedules. For example, perches, and solid or perforated elevated platforms are increasingly being used. These offer the animals the possibility to move three-dimensionally and perch (Kaukonen et al., 2017a; Riber et al., 2018; de Jong and Gunnink, 2019). At the same time, they offer the possibility to structure the environment. Straw bales, wood shavings bales or similar are offered as elevated resting area and to stimulate exploration; Additional modifications or resources can be present, according to, e.g. quality assurance schedules. For example, perches, and solid or perforated elevated platforms are increasingly being used. These offer the animals the possibility to move three-dimensionally and perch (Kaukonen et al., 2017a; Riber et al., 2018; de Jong and Gunnink, 2019). At the same time, they offer the possibility to structure the environment. Straw bales, wood shavings bales or similar are offered as elevated resting area and to stimulate exploration; (Kells and Borja, 2001; Bailie et al., 2013; Bailie and O'Connell, 2014; Riber et al., 2018). Pecking stones or other pecking objects are also provided to stimulate explorative behaviour (Riber et al., 2018) and peat boxes to stimulate dustbathing (Vasdal et al., 2019b). Three-dimensional structures are often lacking, although, platforms in different variants (littered jump tables or perforated/slatted floors) might be available. Variants of elevated perforated platforms are currently being developed that enable the removal of excrement, which is usually not done in floor housing systems.

Typically, indoor floor systems are used for fast growing broiler chickens at high stocking densities (max. 42 kg/m^2 according to Directive 2007/43/EC[5]), but lower stocking densities may also be applied when required by legislation, quality assurance or label programs. Also slower-growing hybrids at lower stocking densities can be housed fully indoors (e.g. for 'Chicken of Tomorrow' production concepts in the Netherlands (Saatkamp et al., 2019)).

There are two ventilation options, forced ventilation at the ridge or the front of the building or natural ventilation. One example of the latter is the so-called Louisiana barn (Louton et al., 2018), which is a barn concept based on a natural ventilation and comparably large windows which offers animal-outdoor climate contact. To achieve the chick's preferred temperature, barns are usually heated via gas radiators, or chicks might be pre-raised in a conventional system and moved to the Louisiana barn for the part of the rearing period where high temperatures are no longer required. As the ventilation has a direct influence on the climate of the barn, especially temperature and humidity, it is mostly automatically controlled.

A multi-tier floor system exists for rearing broiler chickens (Patio™ (van de Ven et al., 2009)), although this system is not commonly applied in Europe. The system combines on-farm hatching with rearing of broiler chickens (see also Section 3.3.2). One unit consists of two rows with 6 tiers each that are separated by a central corridor. Tier width is 2.34 m and the height of one tier is 0.75 cm. The plastic floor of a tier is fully covered with substrate, and feeders, drinkers and light conditions are similar as in traditional floor systems. The system can be combined with automated loading as each tier consists of a conveyor floor that can be moved to remove the chickens from the system. There is a specific ventilation system installed to ensure fresh air at chicken level (Van de Ven et al., 2009; Patio™). With respect to management, the farmer needs to check the birds from the corridor and cannot walk through the house, which differs from traditional floor systems.

Because of the all-in and all-out procedure, a service period with appropriate hygiene measures (cleaning and disinfection) followed by an empty period takes place between rearing periods. The manure, which consists mostly of excrements and the litter from the beginning of the rearing period, will be removed from the barn within this service period. There is no intermittent manure removal in broiler housing, except for newly developed systems that offer raised perforated platforms with a manure belt underneath. These systems are not in practice yet.

Figure 8: Indoor floor housing system without windows (upper picture (A); Photo Credit: Ingrid de Jong), and indoor floor housing system with roof windows, metal round perch and bales as enrichment (B) (de Jong and Gunnink, 2019)

3.3.4. Chicken for meat production kept on Floor systems (Indoor) with covered veranda

Floor housing systems with covered veranda correspond to the floor housing system described in the previous section (Section 3.3.3), with the exception that a covered area is attached, usually at one (long) side of the house (Figure 9). This area, known as a winter garden or (covered) veranda, is accessible to the broilers by popholes along the long side of the building, at least during the day. Access to the covered veranda depends on the temperature requirements and thus the age of the animals. The covered veranda is protected against predators and wild birds or other animals and usually also against extreme weather conditions by a roof; however, it is not heated, and it is often open via a net to outdoor, at least on one side. This is to provide the animals with outdoor temperature and natural light. The area is also littered (usually with the same substrate as the indoor house) with a concrete foundation underneath. This housing system is offered to both fast- and slower-growing hybrids with a longer rearing period, and might be combined with a lower stocking density, windows and environmental enrichment (e.g. the Better Life one Star system in the Netherlands (Vissers et al., 2019)). The exact requirements are dependent on guidelines, e.g. quality assurance schemes. The additional floor area as provided by the covered veranda can be included or excluded in the minimum floor area that should be provided, depending on legal aspects or other requirements (Louton et al., 2019; Mench et al., 2021).

Figure 9: Indoor floor housing with popholes that provide access to the covered veranda (left side) (upper picture) and pophole to covered veranda (lower picture). (Photo credit: Wageningen Livestock Research)

Floor housing with attached covered verandas can be found in several EU member states although there is yet little published information. Veranda access is first offered when the birds are 21–28 days of age depending on the outside climatic conditions (Goransson et al., 2020). Outdoor climatic conditions (temperature, humidity and wind) is a critical point for the birds' health (related to the feather coverage) as well as the birds' actual use of the veranda. The veranda might offer a complex enriched environment (Riber et al., 2018). Research is still ongoing on how to facilitate chickens' use of the covered outdoor area (Jessen et al., 2021a). Verandas, if well managed, provides the broiler chickens with more choice in their environment.

3.3.5. Chicken for meat production kept on floor systems with free range

Floor housing systems with free-range access correspond to the floor housing system described in Section 3.3.3, with the exception of an adjacent outdoor area accessible to the broilers via popholes. A covered veranda may be built in between the barn and the range such that the access to the outdoor area is via the veranda, which might facilitate the birds to go outside. To increase accessibility, the popholes are usually distributed along the long side of the building. Cover, either manmade structures or tall and dense vegetation such as trees and shrubs, is often provided for the broilers in the outdoor area, but EU legal requirements for this protection only exist for the organic production (Commission Implementing Regulation (EU) 2020/464[8]). Free range is mandatory for organic production of broilers and, therefore, predominantly associated with this form of production. However, there is a growing interest for free-range systems among conventional producers. Different broiler hybrids might be used as the duration of the rearing period differs between production systems, with a reduced growth rate in the organic production system. These hybrids might also differ in their ability to make use of the free range and their need for low height differences or the provision of ramps to the outside area. In addition to the broiler hybrids used, the difference between non-organic production and organic production is primarily to be found in the feed and space available. The stocking density is significantly reduced in organic production; the maximum stocking density is 21 kg/m^2 (Commission Regulation (EC) No 889/2008[9]), whereas conventional broilers may be kept at up to 42 kg/m^2 (Council Directive 2007/43/EC[5]). In addition, different sizes of outdoor areas have to be provided per organic broiler; 1 m^2 for young roosters of laying lines (so-called brother cocks), 4 m^2 for all other genetics, including dual-purpose chicken as well as poulards and capons. Organic broilers will also become older as the rearing period is prolonged due to lower daily weight gain. They are kept until minimum 81 days of age (a requirement if the hybrid is not defined as slower-growing with a corresponding low growth rate (not specified further)), but often the hybrid used has a slower growth rate and the broilers are therefore kept for a shorter period, e.g. 53–63 days of age. This in turn results in different activity levels between hybrids and different demands on the husbandry system.

An outdoor area provides the broilers with greater opportunities of performing natural behaviours. In particular, foraging behaviour, exploratory behaviour, dustbathing and sunbathing are strongly promoted by access to a free range, resulting in an increased likelihood of fulfilling the behavioural needs of the broilers (El-Deek and El-Sabrout, 2019). An outdoor area provides the broilers with greater opportunities of performing natural behaviours. In particular, foraging behaviour, exploratory behaviour, dustbathing and sunbathing are strongly promoted by access to a free range, resulting in an increased likelihood of fulfilling the behavioural needs of the broilers (El-Deek and El-Sabrout, 2019; Sanchez-Casanova et al., 2019). Other behaviours may also be affected by availability of an outdoor area. For instance, when providing an environment with more stimuli, the locomotion may increase (El-Deek and El-Sabrout, 2019). Increased activity may improve leg bone parameters and have a positive effect on walking ability (Reiter and Bessei, 2009). If the birds make good use of the outdoor area, the stocking density indoor is automatically reduced during daytime, which slows down the speed of which the bedding deteriorates, resulting in reduced occurrence of contact dermatitis and increased resting comfort, as seen in comparisons of broilers kept with different space allowances (Hall, 2001; Knierim, 2013). Other behaviours may also be affected by availability of an outdoor area. For instance, when providing an environment with more stimuli, the locomotion may increase (El-Deek and El-Sabrout, 2019). Increased activity may improve leg bone parameters and have a positive effect on walking ability (Reiter and Bessei, 2009). If the birds make good use of the outdoor area, the stocking density indoor is automatically reduced during daytime, which slows down the speed of which the bedding deteriorates, resulting in reduced occurrence of contact dermatitis and increased resting comfort, as seen in comparisons of broilers kept with different space allowances (Hall, 2001;

[8] Commission Implementing Regulation (EU) 2020/464 of 26 March 2020 laying down certain rules for the application of Regulation (EU) 2018/848 of the European Parliament and of the Council as regards the documents needed for the retroactive recognition of periods for the purpose of conversion, the production of organic products and information to be provided by Member States. OJ L 98, 31.3.2020, pp. 2–25.

[9] Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control. OJ L 250, 18.9.2008, pp. 1–84.

Knierim, 2013). Moreover, a reduction of the stocking density can improve walking ability, probably due to increased activity of the broilers (Blokhuis and Vanderhaar, 1990; Lewis and Hurnik, 1990; Knierim, 2013). However, in stationary poultry barns, the outdoor area closest to the popholes is typically barren, both due to wear from the birds, but also due to soil compaction and draining measures (van Niekerk, 2016). This is unfortunate, as broilers often do not move far from the house, and thus will stay within this barren zone, when using the outdoor range (Rodenburg et al., 2004).

Low use of the outdoor area is often reported in studies of broilers with access to a range (Dawkins, 1989; Dawkins et al., 2003; Taylor et al., 2017c; Jessen et al., 2021a). Thus, to gain the abovementioned welfare benefits from access to an outdoor area, the range has to be attractive to the broilers for high use to occur. This likely includes easy access through the popholes, as shown in laying hens (Pettersson et al., 2016), and good vegetation cover on the range, including both ground vegetation promoting foraging behaviour (Fonseca de Almeida, 2012) and tall vegetation for shelter and protection (Dawkins et al., 2003; Dal Bosco et al., 2014; Stadig et al., 2017b). Covered verandas have been proposed to provide a smooth transition between the darker indoor barn and the bright outdoor area. Since verandas are covered and offer protection from predators, it is likely that broilers perceive them as a safer place than an outdoor area (Newberry and Shackleton, 1997). Low use of the outdoor area is often reported in studies of broilers with access to a range (e.g. Dawkins, 1989; Dawkins et al., 2003; Taylor et al., 2017c; Jessen et al., 2021a). Thus, to gain the abovementioned welfare benefits from access to an outdoor area, the range has to be attractive to the broilers for high use to occur. This likely includes easy access through the popholes, as shown in laying hens (Pettersson et al., 2016), and good vegetation cover on the range, including both ground vegetation promoting foraging behaviour (Fonseca de Almeida, 2012) and tall vegetation for shelter and protection (Dawkins et al., 2003; Dal Bosco et al., 2014; Stadig et al., 2017b). Covered verandas have been proposed to provide a smooth transition between the darker indoor barn and the bright outdoor area. Since verandas are covered and offer protection from predators, it is likely that broilers perceive them as a safer place than an outdoor area (Newberry and Shackleton, 1997).

To prevent attacks from ground predators and to keep the broilers to the designated area, the outdoor range is typically fenced. Other strategies against aerial predators and direct contact with wild birds are also advised. To limit contact with wild birds and their droppings, feed and water, if available in the outdoor area, is usually provided under a cover, and might be suppressed to avoid attracting wild birds to the range in the context of highly pathogenic avian influenza. The area closest to the barn poses a challenge due to soil compaction, for which reason the management of this type of housing also includes maintenance of the outdoor area. The simultaneous use of the outdoor area with sustainable production of crops such as fruit or poplars for biofuels is of growing interest.

3.3.6. Chicken for meat production kept in mobile systems with free range (niche production)

Rearing of chickens in mobile sheds has been a niche so far, but the system is gaining increasing interest (for an example see Figure 10). The types of housing are not as uniform as in floor housing, but in general two different variants can be found: fully mobile housing with typically a few hundred chickens that are regularly moved to new areas and partially mobile housing, which usually involves larger sheds that are only moved between flocks. The latter may not have a solid floor. The houses are mostly self-sufficient and have structures inside, such as feed and water lines and, sometimes, straw bales or perches. Mainly slower-growing broiler hybrids are used in this system. In some of the mobile systems usually found for laying hens, manure removal is possible, especially underneath the perches if provided. Houses for broilers are just developing and usually do not have a second level indoor as found in the mobile houses for laying hens. The hygiene management of the outdoor area is significantly improved by regular relocation. The relocations of the houses also ensure good vegetation cover throughout the rearing period even in the area closest to the house. Due to the smaller flock sizes and ideally due to direct access (low height difference and large popholes/openings) to an outdoor area with good vegetation cover, mobile housing has the advantage that many broilers use the range. However, the management of mobile housing is complicated by the fact that broiler chickens have high demands on the temperature supply in the first days. Split rearing variants, with pre-rearing in other housing systems and later transfer to the mobile houses, are, therefore, also encountered. In comparison to the floor system with free range, the mobile system has the capacity of ensuring even greater opportunities for foraging and exploratory behaviours, as the vegetation cover near the house is renewed on a regular basis by the movements of the house. Furthermore, the smaller group sizes reduce the risk of being excluded from access in/out of the house by dominant birds monopolising the popholes. Some mobile houses open completely along the long side and thus offer large-area entrances and exits. Another benefit of the mobile system compared to indoor systems with a free range is in relation to predation; the smaller ranges (due to smaller flock sizes) result in decreased distance to the house and thus faster access to a safe place. On the negative side, mobile houses may be part of the rotation between fields of different crops, including pasture for animals, for which reason shelter in terms of trees and bushes may not be present. The insulation and type of ventilation also have a particular influence on the animal welfare of broilers in mobile housing. Passive airflows can become critical during hot periods, so active ventilation is preferable.

Figure 10: Example of a mobile house, in this case for laying hens (Photo Credit: Flemming Haugaard Haugaarden Aps)

3.3.7. Broiler breeders kept in floor systems

In contrast to cage housing, where broiler breeders are kept in smaller groups (up to 100) on wire floor, breeders in floor systems are kept in larger groups of hundreds or thousands of birds directly on the floor of the building. This large group may be sub-divided into smaller groups within the building, when used for selection. The floor may be entirely covered with litter or there may be a raised slatted area covering about 30–50% of the total floor area. The stocking density is normally around seven up to 10 birds/m^2 for females and between 4 and 8 birds/m^2 for males during rearing and between 5 and 7.5 birds/m^2 during production (de Jong and van Emous, 2017). In some publications, it is unclear whether the stocking densities are for females only or for both males and females during the production period, potentially leading to underestimation of the stocking densities in some cases.

Floor systems so called 'feeding stations' allow selection for growth rate since each chicken is identified with a RFID chip and will enter a 'station' to be fed automatically. At this occasion, the chicken is weighed and the amount of feed delivered registered, on a daily basis.

In many European countries, the toes of male chicks are clipped (which can be the toe that points backwards or inwards) and the males of some lines or crosses are de-spurred. Mutilations such as comb dubbing is no longer standard procedure in Europe and estimated to be less than 10% (EFSA AHAW Panel, 2010). In some European countries, beak trimming has been or will be prohibited soon for both sex or females only. These different mutilations are intended to reduce skin and integument damage when males and females are housed together.

Chicks and pullets of broiler breeders are reared in the same or floor systems similar to the ones in which they will be kept in during the production period. Unless prohibited by law (e.g. in Switzerland), barns without natural light are preferred in breeders to easily control day length. The standard broiler breeder rearing unit houses in Europe are mechanically ventilated. The sexes are reared separately; preferably in different buildings so light control can be optimised for the sexes that mature at different rates and to control the amount of feed separately for the sexes. See photo showing an example of a broiler breeder-rearing house in northwest Europe (Figure 11) and scheme of a broiler breeder-rearing house (Figure 12).

Specific enrichment is usually not provided.

Figure 11: Example of a broiler breeder-rearing house in northwest Europe (De Jong and van Emous, 2017; Photo credit: Wageningen Livestock Research)

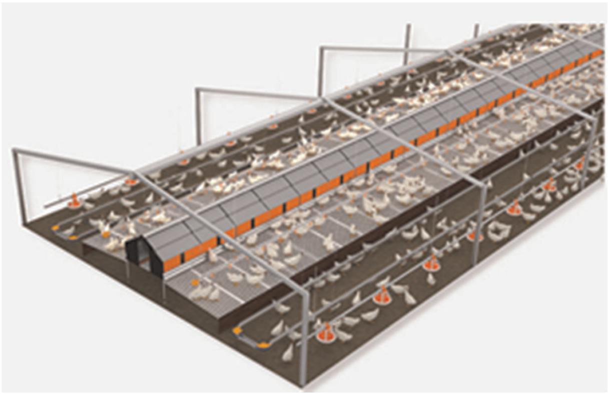


Figure 12: Broiler breeder-rearing house © Big Dutchman

During the egg-laying period for broiler breeders, including grandparent lines, and in systems with a raised slatted area, nests are located on top of a raised slatted area. This slatted area is above a manure pit in the middle of the barn but unlike in a similar system for laying hens, manure remains in the barn until the end of the production period. A drinker line is installed above each manure pit, ca. 60 cm in front of the nest. Either suspended or standing chain feeding lines are mounted on the left and the right of the manure pit. Depending on the width of the house, an additional circuit can be included above the manure pit. The males should be fed separately near the long side of the house. A large part of the floor is covered with litter because mating is supposed to take place on the litter. Slats can be offered in 'steps' leading up to the raised nests as in the Big Dutchman system 'Bel Etage Aviary System'. Males do not jump on the raised slats as often as females and are fed with separate feeders on the litter. For that reason, females can avoid (aggressive) males to some extent by occupying the slats or hiding in the nests. Barriers are sometimes used to reduce the frequency of unwanted sexual behaviour in large groups (Leone and Estévez, 2008). Outside Europe, group nests are mainly placed on the floor and no raised slats are provided (van den Oever et al., 2021). In an experimental system introduced in The Netherlands, broiler breeder males and females are separated for 5 h a day using separate feeding systems and a movable partition (Van Emous and de Jong, 2013). Experiments showed more voluntary and successful mating, as well as improved sexual behaviour and better plumage condition of the females within this system. Barriers are sometimes used to reduce the frequency of unwanted sexual behaviour in large groups (Leone and Estévez, 2008). Outside Europe, group nests are mainly placed on the floor and no raised slats are provided (van den Oever et al., 2021). In an experimental system introduced in The Netherlands, broiler breeder males and females are separated for 5 h a day using separate feeding systems and a movable partition (Van Emous and de Jong, 2013). Experiments showed more voluntary and successful mating, as well as improved sexual behaviour and better plumage condition of the females within this system.

Stocking densities are usually quite low and comparable, e.g. in Germany and Switzerland: 7 animals per m^2 usable area. It may vary between the different sexes, e.g. 4–8 birds/m^2 (males) and 7–10 birds/m^2 (females). In some European countries, such as France, dwarf females like Sasso, which weigh ca. 2,350 g instead of more than 4,100 g of a Ross 308 female at the end of production (66, resp. 62 weeks of age) can be used as parents. In these cases, there can be more birds per m^2.

According to the Council of Europe, perches are required for adult broiler breeders so that all animals can perch simultaneously at night (Council of Europe, 1995). They must be constructed in a way to avoid foot lesions (see Supp. II. A. 3, Council of Europe, 1995). Lower Saxony (Germany) specified the requirements regarding perches for broiler breeders. Half of the animals must have 20 cm perch length available. Perches must be at least 5 cm above the raised slats and at least 20 cm above the litter.[10] Likewise, in Switzerland, 14 cm perch length per bird is required for adult laying hens, layer breeders, and broiler breeders and 11 cm per bird are required for (breeder) pullets. The perches (often made from metal) for pullets are offered on a construction like a pyramid. Alternatively, the perches are on raised racks. Although the aerial perches must be provided on at least two different heights with a minimum at 50 cm,[11] the perches for the adult broiler breeders are often mounted directly on the elevated slats. These can be made from plastic and may be mushroom shaped. Alternatively, metal perches hang above the raised slats.

For grandparent stock, the company Aviagen™ sets the animal density to 6 hens/m^2 or 5 males/m^2 but they are still kept in large flocks. For great grandparent stock, the layout is similar to parent stocks, so with nests on the slats and a partial litter area. The animal density, however, is even lower than for parent stock; 4–5 birds/m^2 for great grandparent and pure lines. Furthermore, pure lines are often kept in small groups. These groups can be as small as 10 hens and 1 male, but sometimes groups are larger to look at the effect of male-male competition. Nests are mainly family nests, but some individual nests are used as well. Data might be gathered through genomics techniques to link the eggs to the correct birds.

In floor systems for broiler breeders, natural mating is performed, and males might be exchanged for younger individuals during production to prevent lower fertility rates of males over 40 weeks of age (called 'spiking'). However, this might increase the risk of introduction of pathogenic agents by introducing animals from outside the farm/building and this might also lead to more 'inability to avoid unwanted sexual behaviour' for the females.

After about 2 weeks of *ad libitum* feeding, feed restriction up to 70% of the *ad libitum* diet (depending on the hybrid and age) is carried out. There is also sometimes restricted access to water, since some birds may develop polydipsia or persistently interact with the drinkers, both which can result in wet and poor litter quality. Males and females follow separate feeding programmes, which is the main reason for housing them separately during rearing. For more details on feed restriction and literature, see Section 3.4.2.7 Welfare consequence 'Prolonged hunger'.

3.3.8. Broiler breeders kept in individual unfurnished cages

Individual unfurnished cages are used by some breeding companies in Europe for broiler breeders even if some birds may later be moved to floor systems. Cages can be of different size, depending on whether the birds are males or females. According to EFFAB, the sizes of cages for females range between the following values: Length*Width*Height: 34–52 cm * 24–49 cm * 38–59 cm and the sizes of cages for males range between: Length*Width*Height: 34–52 cm * 24–49 cm * 47–65 cm (questionnaire to EFFAB, see Appendix A). In other cases, individual cages may be used only for males, while females are kept in group cages. When they are used, it is most likely for grandparent, great grandparent and pedigree breeding birds of certain pure lines.

Single cages allow the recording of individual data (e.g. egg production) and avoid selection of preferred hens by the males. In order to select broiler breeders for traits like feed efficiency, data on individual feed consumption and production parameters must be accurately measured. As for now, with current technology, this is not possible when birds are housed in groups as individual droppings cannot be collected; so, for these animals that are used for selection, individual housing is considered necessary. New technology to assess traits of individuals in groups, like feed consumption, is under development, but not yet used systematically (questionnaire to EFFAB, see Appendix A).

[10] Tierschutz; Mindestanforderungen an die Haltung von Masthühner-Elterntieren (Animal welfare; minimum requirements for the keeping of broiler chickens as parents). Decree of the Ministry of Agriculture of 21.1.2015 - 204.1-42503/2-971.

[11] Ordinance 455.1 of the Swiss Federal Council of 23rd April 2008 on the protection of animals (Ordonnance sur la protection des animaux). p. 114.

Individual housing is also necessary to control the provision of sperm of particular males to the selected females and involves handling of the animals. Artificial insemination (AI) ensures efficient selection, an inbreeding coefficient below 1%, and conservation of genetic diversity, especially in lines of small population number, e.g. heritage lines. Under free-mating conditions when males have free access to females, as is common in broiler breeders at the production level of brooding eggs, a male might not choose to mate with certain hens. At the same time, dominant males might exclude less dominant males from mating and decrease genetic diversity and aggressive and dominant males are inadvertently reflected in the offspring.

Selection is applied on grandparent, great grandparent and pedigree breeding birds of certain lines in very few companies in a few countries in Europe. The umbrella organisation of EFFAB estimates that, in 2021, about 360,000 individual cages were used in Europe for birds used for selection. Of those, 3,000–4,000 individual unfurnished cages are used just for a short period of time (i.e. 2 weeks) to collect individual data on, e.g. feed consumption. Later, the birds kept in these cages are moved to floor systems under group housing. For the majority of the cases, individual cages may be used for longer periods of time only for males, while females are kept in collective cages. These numbers are probably an upper estimate since besides broilers, it may include also laying hen breeders and other species of fowl like ducks and guinea fowl. The percentage of males or females that are housed in individual cages varies with the type of production (e.g. layers, broilers, heritage lines with small population sizes).

The individual cages are generally unfurnished cages (no nest box, litter or perch) although some of the companies of EFFAB claim to provide perches in individual cages, but only for males and in cages that remain very small (EFFAB, personal communication, 8 September 2021).

3.3.9. Broiler breeders kept in furnished collective cages

Besides selection on individual traits that can be performed in single-housed birds, selection on social traits like the selection to reduce feather pecking and improve social behaviour including reproductive performance, is performed on family groups in collective (multi-bird) cages where, for example, the family groups without feather loss and mortality may be selected.

According to EFFAB, in Europe, about 75,000 collective cages are used that have some, but probably very limited, enrichment. The exact type of enrichment is unknown, as well as the prevalence, e.g. nests are sometimes provided when natural mating is used, but not always and not by some of the breeding companies. Depending on the company and the age of the barn, the number of animals per cage varies (e.g. from 1 male and 10 females up to 8 males and 65 females). Since the size of the cage depends on the number of birds, the size of collective cages is also very variable; L*W*H: 64*120*46 cm and 60*45*40 cm (questionnaire to EFFAB, see Appendix A). The scientific literature on housing practices of broiler breeders in collective cages is very limited. A recent publication from Pakistan (Khan and Khan, 2018) compared the production performance of Hubbard breeders under a controlled environment housed in collective cages and under floor housing and detected higher performance (defined as better feed efficiency, better survival, more eggs, and more hatchlings) in the collective cages. They described the cage housing of Hubbard breeders as follows: 'Hens were housed in Hot Dip Galvanized 3-tier cages, measuring 658 cm^2 area per female bird (1,974 cm^2 area in total for 3 birds per cage), 1,645 cm^2 area per male bird and one male per cage'. These cages were barren and without nests. No information about impact of this husbandry system on bird welfare was reported in this paper. Even if the space allocation per bird is the same, the total space per bird will be higher in collective cages than in individual cages. These furnished cages usually have a laying nest, perches and a small litter area (de Jong and Swalander, 2012). The provision of, e.g. litter on the floor of the cage that would be suitable for dustbathing and ground scratching, is often incompatible with the technology of cages or considered impractical. This means that in cages, including furnished collective cages, most of the floor consists of wire so faeces can be regularly removed.

Rearing broiler breeders in cages generally results in heavier and fatter pullets than those housed in floor systems (Purvis, 1978; Leeson and Summers, 1985) but Hubbard broiler hens in a floor system were heavier and consumed more feed than the hens kept in cages in the study by (Khan and Khan, 2018). All the birds of the study by (Khan and Khan, 2018) were raised in a floor system which can explain the different results to other studies that considered also rearing the birds in cages. The reasons why broiler breeder hens are usually heavier in cage systems include that they do less exercise in cages (Oscai et al., 1972) or reduced heat loss related to stocking density (DeShazer and Mather, 1981). This might seem an advantage regarding feed efficiency, but it is less suitable for breeders (pullets) where higher body weights at maturity or during production lead to lower viability and fecundity in both sexes. This was even more a problem with dwarf hybrids with their propensity to fatness (Calabotta et al., 1983) but it is unclear if this is still true for modern hybrids.

Additionally, weekly AI performed in caged birds is very labour intensive and may not always be done in a gentle way (see description under the welfare consequence 'handling stress' 3.4.2.10). Thus, labour costs of AI, the higher risk of obesity, and the bad image of cages and the negative impact in terms of animal welfare seem to be reasons why cage housing system for broiler breeders are not used for production in Europe except the animals used in selection programmes as outlined above.

3.3.10. Broiler breeder kept in floor system with multi-tier systems

Although open multi-tier systems called aviaries have become popular as non-cage intensive housing systems for laying hens and layer breeders, they are rarely used in broiler breeders. There have been attempts to adapt a multi-tier aviary system to broiler breeders in Germany and the Netherlands (Keulen, 1995; Damme, 1996). The advantages of these systems include a higher number of animals per ground area and the possibility to remove faeces automatically for a lower ammonium concentration, improving the bird's welfare. There are increased possibilities of exploration for birds moving in three dimensions, for example by flying between different levels, and so increased possibilities to avoid forced mating by males. After tests of the aviary 'Voletage' of the company Volito, (Damme, 1996) concluded that this system was optimally suited for the housing of broiler breeders in terms of production of first-grade hatchlings as well as lower barn costs, heating costs and better climate control. However, the Ross 308 and Cobb broiler breeders in the cited studies were from the 1990s and the results might not be applicable to current breeders. Two decades later, Gebhardt-Henrich et al. (2018) found more floor eggs in an aviary system than in control pens with a floor system for the hybrid Ross 308. The aviary system enabled more perching behaviour especially at night than in a floor system with wooden perches. Mating behaviour was not impaired by providing a multi-tier system and perches, although females used perches and tiers to avoid males and fewer forced mating took place (Gebhardt-Henrich et al., 2020). In conclusion, although open multi-tier systems are not in use for broiler breeders to the same extent as it is for laying hens and laying hen breeding flocks, these systems offer potential to combine the economical production of brood eggs with fulfilling welfare requirements like perching and avoiding/decreasing forced mating.

3.4. Highly relevant WCs, related ABMs on farm for broilers, hazards, preventive and corrective measures

3.4.1. List of welfare consequences that were ranked as highly relevant to broiler chickens

The EFSA Task Force on animal welfare has defined a list of welfare consequences that may apply to animals in their different husbandry systems. These welfare consequences impact negatively animal welfare by inducing discomfort, distress, stress, fear, frustration and/or pain to animals. The complete list of 33 welfare consequences and the overarching negative affective states can be found in EFSA AHAW Panel (2022b). The list and description of the 19 welfare consequences ranked as highly relevant for broilers is displayed in Table 5.

Table 5: List of specific welfare consequences applicable to broilers on farm (adapted from EFSA AHAW Panel (2022b))

#	Welfare consequence	Description
1	Restriction of movement	The animal experiences stress and/or negative affective states such as pain, fear discomfort and/or frustration due to the fact that it is unable to move freely, or is unable to walk comfortably (e.g. due to overcrowding, unsuitable floors, gates, barriers).
2	Resting problems	The animal experiences stress and/or negative affective states such as discomfort, fatigue and/or frustration due to the inability to lie, rest comfortably or sleep (e.g. due to hard flooring).
3	Group stress	The animal experiences stress and/or negative affective states such as pain, fear and/or frustration resulting from a high incidence of aggressive and other types of negative social interactions, often due to hierarchy formation or competition for resources.
4	Sensory under and/or overstimulation	The animal experiences stress and/or negative affective states such as fear and/or discomfort due to visual, auditory or olfactory under/overstimulation by the physical environment.
5	Handling stress	The animal experiences stress and/or negative affective states such as pain and/or fear resulting from human or mechanical handling (e.g. sorting and vaccination).
6	Isolation stress	The animal experiences stress and/or negative affective states such as frustration and/or fear resulting from the absence of social contact with conspecifics.
7	Inability to perform comfort behaviour	The animal experiences stress and/or negative affective states such as discomfort and/or frustration resulting from the thwarting of the motivation to maintain the function and integrity of the integument (e.g. cannot keep clean, scratch).
8	Inability to avoid unwanted sexual behaviour	The animal experiences stress and/or negative affective states such as pain and/or fear resulting from inability to avoid forced mating.
9	Inability to perform exploratory or foraging behaviour	The animal experiences stress and/or negative affective states such as frustration and/or boredom resulting from the thwarting of the motivation to investigate the environment or to seek for food (i.e. extrinsically and intrinsically motivated exploration).
10	Predation stress	The animal experiences negative affective states such as fear resulting from being attacked or perceiving a high predation risk.
11	Prolonged hunger	The animal experiences craving or urgent need for food or a specific nutrient, accompanied by a negative affective state, and eventually leading to a weakened condition, as metabolic requirements are not met.
12	Prolonged thirst	The animal experiences craving or urgent need for water, accompanied by a negative affective state and eventually leading to dehydration, as metabolic requirements are not met.
13	Heat stress	The animal experiences stress and/or negative affective states such as discomfort and/or distress when exposed to a high effective temperature.
14	Cold stress	The animal experiences stress and/or negative affective states such as discomfort and/or distress when exposed to low effective temperature.
15	Locomotory disorders (including lameness)	The animal experiences negative affective states such as pain or discomfort due to impaired locomotory behaviour induced by, e.g. bone, joint, skin or muscle damage.
16	Soft tissue lesions and integument damage	The animal experiences negative affective states such as pain, discomfort and/or distress due to physical damage to the integument or underlying tissues, e.g. multiple scratches, open or scabbed wounds, ulcers and abscesses. This welfare consequence may result from negative social interactions such as aggression, tail-biting, from handling or from damaging environmental features, or from mutilation practices (e.g. tail docking).

#	Welfare consequence	Description
17	Bone lesions (incl. fractures and dislocations)	The animal experiences negative affective states such as pain, discomfort and/or distress due to fractures or dislocations of the bones (excluding those fractures leading to locomotory disorders).
18	Gastro-enteric disorders	The animal experiences negative affective states such as discomfort, pain and/or distress due to impaired function of the gastrointestinal tract resulting from, for example nutritional deficiency and infectious, parasitic or toxigenic agents.
19	Umbilical disorders and hernias	The animal experiences negative affective states such as discomfort and/or pain due to inflammation of the navel or any type of hernias.

3.4.2. Description of the welfare consequences identified as highly relevant in the context of broiler chickens kept for meat production and related ABMs

The working group described the highly relevant welfare consequences applicable to *Gallus gallus* used for meat production as well as the related ABMs. During a ranking exercise (for method see Section 2.3.1), the highly relevant welfare consequences were identified for each husbandry system and category of bird and are summarised in Table 6. Each welfare consequence selected as highly relevant is presented in detail in the Sections 3.4.2.2–3.4.2.20 and ABMs which may be used to assess the welfare consequence as well as preventive, corrective and mitigative measures.

Table 6: Distribution of highly relevant welfare consequences of broilers across ten husbandry systems

Welfare consequence	Day-old chicks		Chickens for meat production				Broiler breeders			
	HH	HF	FSI	FSCV	FSFR	MH	IC	CC	BBFS	MT
Bone lesions										X
Cold stress	X					X				
Inability to perform comfort behaviour			X				X	X		
Inability to perform exploratory or foraging behaviour			X				X	X		
Isolation stress							X			
Gastro-enteric disorders			X	X	X	X				
Prolonged thirst	X								X	X
Heat stress						X				
Prolonged hunger	X						X	X	X	X
Handling stress	X						X			
Locomotory disorders			X	X						
Predation Stress					X	X				
Restriction of movement			X				X	X		
Resting problems	X		X	X	X	X	X	X	X	
Group stress			X	X	X				X	X
Soft tissue and integument damage			X	X	X		X	X	X	X
Umbilical disorders		X								
Inability to avoid unwanted sexual behaviour								X	X	X
Sensory under- and overstimulation	X	X								
Total	6	2	8	5	5	5	8	7	6	6

HH: Day-old chicks hatched in hatchery; HF: Day-old chicks hatched on farm; FSI: Chickens for meat production kept in floor systems (indoor); FSCV: Chickens for meat production kept in indoor floor systems with covered veranda; FSFR: Chickens for meat production kept in floor systems with free range; MH: Chickens for meat production kept in mobile houses;
IC: Broiler breeders kept in individual cages; CC: Broiler breeders kept in furnished collective cages; BBFS: Broiler breeders kept in floor systems; MT: Broiler breeders kept in open multi-tier systems.

ABMs applied to assess the welfare consequences may include parameters related to body condition (e.g. plumage score), behaviour (e.g. time spent doing a certain activity), physiology (e.g. cloacal temperature) or health status (e.g. sick or dead animals).

3.4.2.1. Measurement of ABMs

For each welfare consequence, different ABMs may exist and these can potentially be assessed through different methods. This section includes a general description of the ABMs' measurement general consideration. This information will not be described again later. In addition, in each section describing the welfare consequences below (Sections 3.4.2.2–3.4.2.21), for each ABM only specific information is provided about methods to measure the ABMs. The approach is not exhaustive and only main methods are provided here. For full details, the reader should refer to the papers cited.

ABMs relating to body condition, health status and physiological state

These ABMs are measured as either binary (yes/no: e.g. dead, sick, having a broken bone), categorical (e.g. scoring of plumage cleanliness (0/1/2)) or continuous variables (e.g. weight, cloacal temperature, level of hormone). However, most (welfare) variables, even if measured in categories, have an underlying continuous distribution and can be more accurately assessed on a continuous (e.g. visual analogous) scale.

Depending on the scale of measurement, there are different ways to express the results: it can be a prevalence (e.g. proportion of birds with a bone fracture; proportion of birds with plumage score 2), a mean score (e.g. mean plumage score of the birds observed) or a mean value (e.g. mean weight loss). The measures can take place by handling animals (e.g. scoring plumage, weighting), looking at them without handling (e.g. transect method), or by automatic measurement (e.g. automatic weighing, infrared camera temperature measurement, video scoring system of plumage cleanliness). For physiological data, the sampling is either invasive (e.g. blood sampling) or not (collection of droppings or feathers).

ABMs relating to behaviour

Behaviours can be measured in terms of time budget dedicated to each activity (e.g. time spent doing a certain activity), or in terms of frequency of the behaviour in a group of animals, expressed either as percentage of animals performing the behaviour per unit of time or frequency per individual per time unit. It requires an experienced observer to differentiate the different types of behaviour, and it can be time consuming with large sample sizes or when patterns during the day need to be observed.

Measurable characteristics of a behaviour include its frequency (prevalence) and its duration (the length of time a single behaviour is performed before a transition to a new behaviour). Collecting this information permits a calculation of mean duration (or mean 'bout length'). Some behaviours have a very brief duration, and these are often described as 'events' and only their frequency is recorded. Other behaviours, such as resting, standing or perching, have relatively long durations and can be described as 'states' where frequency, total duration and mean bout length can all be recorded.

Measurement approaches tend to vary depending on group size. In small groups it may be possible to observe individual animals for a specified amount of time, a technique called focal (animal) sampling. Usually, a continuous record from each individual is obtained allowing calculation of both frequencies and durations of each behaviour performed. In larger groups, there are practical difficulties in following individual birds, including marking, identification and track fast-moving animals in a complex house. Nevertheless, the use of RFID tags and readers may allow focal animal information to be obtained on bird movement and location and, if combined with other technologies such as accelerometry, it is increasingly possible to obtain some information on individual behaviour, even within large flocks.

In larger flocks of hens, a scan sampling approach is usually adopted. A selected area in the barn or the range is scanned rapidly, and the number of animals performing each behaviour is recorded, alongside with a note of the total number of animals present in the chosen area at the time of the scan. This approach allows an estimate of behavioural frequencies, but it is not sensitive to measuring the occurrence of sporadic behaviours or those of very brief duration as both might contribute to a bias in the data collection.

When the objective is to focus on just one specific behaviour, for example a specific vocalisation such as a gakel-call. In this case, every occurrence of behaviour is recorded from the group or flock under consideration, using a technique called behaviour sampling.

Specialised studies may record more complex features of behaviour including behavioural structure (e.g. Collins (2008)) and sequencing.

Behaviour is usually recorded either by direct observation by trained individuals or by video recording and subsequent analysis. An advantage of the direct approach is that the observer can adjust their position to keep track of birds that move behind others, for example. However, the presence of an observer can itself affect bird behaviour, and can sometimes be inefficient (e.g. if birds are all resting), and concerns of hygiene also exist, but application of biosecurity measures should avoid this being a problem to enter the barn. Video recordings can be used instead but the scoring is time consuming, not all areas might be visible, and animals may move out of view.

Sampling methods

To assess the prevalence of an ABM or a mean score on a flock, the two most common approaches include observing all animals of the flock or use a flock sample. The first option is often unsuitable, especially if the number of animals in the group is large. The second approach, using a representative sample, is often the only possible approach and allows to save time. This second approach allows an estimation of the true result in the population. In any case, sampling methods and scoring methods must have been previously validated so that the obtained estimation is reliable.

The representativeness of a sample is related to the sampling method. The selection of animals should be: randomised, systematically randomised (e.g. when walking in a barn, pick up one animal every five) or could rely on some stratification (e.g. if 20% of animals are counted in the outdoor range, randomly sample 20% outside and 80% in barn).

The number of animals composing the sample influences the precision of the result, and although larger samples should provide a more precise result, the relationship is not linear normally.

The Welfare Quality Protocol® provides protocols for assessment that have been scientifically validated (Welfare Quality®, 2009).The recommended sample size is between 100 and 150 broilers per flock according to the trait. The protocol outlines how stratification should be performed to obtain a representative sample.

More details about sampling can be found in Appendix E.

Inter- and intra-observer reliability

Measuring behaviour either live or from recordings as well as the scoring of physical traits like feather damage may be prone to observer bias and poor repeatability (Nalon et al., 2014); (Tuyttens et al., 2009). To improve the internal validity of a scoring system and thus ensuring that different people arrive at the same score, training is important. Thus, training by approved trainers is a prerequisite for scoring when using the Welfare Quality Protocol® (Welfare Quality®, 2009) and also when using other scoring systems. Periodically, inter- and intra-observer reliability should be checked because they are essential to determine accuracy and internal validity of a variable (Cohen, 1960; Chen et al., 2009).

In the Sections 3.4.2.2–3.4.2.20, the ABMs corresponding to the 19 highly relevant welfare consequences are described. The ABMs that can assess different welfare consequences, so called iceberg indicators, are described in Section 3.4.2.21.

3.4.2.2. Bone lesions

Description of WC, category of bird and husbandry systems

'Bone lesions' was identified as a highly relevant welfare consequence for female broiler breeders kept in open multi-tier systems. However, it cannot be excluded that these lesions also happen in other systems, but no information is available.

'Bone lesions' include fractures and dislocation (Table 5). Wing and leg fractures do occur in laying hens and can sometimes even lead to mortality (Fulton, 2019). However, there is a lack of investigations into whether and with which prevalence these factures occur in broilers or broiler breeders (Gebhardt-Henrich et al., 2018; Vasdal et al., 2022a). For this reason, the only fractures of the keel bone will be considered, which is known to occur in broiler breeders.

The rationale for including this as a main welfare consequence for female broiler breeders is the severity and the duration if a bone lesion occurs. The severity can be considered as high when a fracture has just happened. Regarding the duration, healing takes time, and some fractures of the keel bone may not heal (Baur et al., 2020) and can therefore be expected to be associated with chronic pain (Nasr et al., 2013). Even after healing, there may be chronic pain or behavioural consequences, for example if there is chronic pain, then movement or flight can be expected to be affected (Rentsch et al., 2019). Although there are several studies on this topic in layers, the true prevalence of these keel bone fractures is not known for broiler breeders.

All eving of keel bone fractures comes from studies on laying hens, where bone weakness has caused many problems such as bone deformation, osteoporosis and fractures. Keel bone fractures have received very little attention in female broiler breeders, and nothing is known concerning broiler breeder males. Data from laying hens cannot be readily extended to broiler breeders because of different genetics, behaviour and housing systems. Genetic differences in the likelihood of keel bone fracture have been demonstrated in laying hens (Candelotto et al., 2017) and broiler breeders (Gebhardt-Henrich et al., 2018). For example, females of the dwarfed Sasso hybrid had more keel bone fractures than females of the Ross 308 hybrid (Gebhardt-Henrich et al., 2018). Housing systems with aerial perches appear to induce a higher rate of keel bone fractures (broiler breeders: (Gebhardt-Henrich et al., 2018)), review of laying hens: (Rufener and Makagon, 2020) while laying hens in aviary systems have lower rates of fractures than non-aviary systems with perches (Rufener and Makagon, 2020). Possibly, laying hens in aviary systems have the opportunity to exercise to strengthen the bones. In one trial with Ross 308 female broiler breeders, keel bone fractures were more prevalent in pens with perches or aviaries than in control (barren) pens (Gebhardt-Henrich et al., 2018). However, in a subsequent trial with Ross 308 broiler breeders, a quarter of hens (24.8%) had moderately or severely deformed keel bones indicative of fractures, and 62% had intact keel bones without a difference in keel bone damage in pens with and without perches (Gebhardt-Henrich et al., 2017b).

The causes are not entirely clear but prolonged pressure on the keel bone while perching (Pickel et al., 2011), falls from elevated structures and collisions with barn equipment, or other causes connected with egg-laying are likely to explain keel bone fractures (Sandilands et al., 2009; Harlander-Matauschek et al., 2015; Thøfner et al., 2020).

Additionally, egg laying at a young age when the keel bone has not been completely ossified and large egg size may lead to bone damage at the tip of the keel bone (Thøfner et al., 2021). As broiler breeders are also selected for early maturation and high rates of egg laying, they may suffer from keel bone damage in a similar way as laying hens.

The onset of keel bone lesions in broiler breeders has not been investigated much, but lesions were found in 46-week-old broiler breeders (Gebhardt-Henrich et al., 2017a; Gebhardt-Henrich et al., 2018). Broiler breeders are normally kept in production until at least 62 weeks of age, which would amount to a minimum duration of this welfare consequence of 14 weeks. The severity ranged from moderate to severe and about a quarter of the birds were affected.

Description, measurement, interpretation and characteristics of ABMs

Keel bone fracture

Definition	'Keel bone fractures' include sharp bends, shearing, and/or fragmented sections of the keel bone (Casey-Trott et al., 2017). There can be indentations along the ventral surface indicating fractures.
Measurement	The occurrence of healed or new keel bone fractures can be assessed by palpation, computed tomography, ultrasound, radiography or an automated 3D camera system (Rufener and Makagon, 2020; Jung et al., 2021). Importantly, the assessment method affects the percentage of fractures that are detected as these methods vary in sensitivity (Rufener and Makagon, 2020; Jung et al., 2021). A keel fracture in a live bird is most typically identified through palpation by the presence of callus material on the ventral and lateral surfaces as a product of the regenerative healing process in the period after the fracture has occurred. The distinction between fractures and deviations is difficult and even impossible in case of minor damage. More precisely, keel bone damage can be identified in radiographs (Casey-Trott et al., 2015, 2017; Rufener et al., 2018) and in some cases, radiographic characteristics are even categorised. A keel fracture in a live bird is most typically identified through palpation by the presence of callus material on the ventral and lateral surfaces as a product of the regenerative healing process in the period after the fracture has occurred. The distinction between fractures and deviations is difficult and even impossible in case of minor damage. More precisely, keel bone damage can be identified in radiographs (Casey-Trott et al., 2015, 2017; Rufener et al., 2018) and in some cases, radiographic characteristics are even categorised (Richards et al., 2011;

	Rufener et al., 2018), or it can be identified by dissection in dead chickens and then visually assessed (Thøfner et al., 2021).
Interpretation	High prevalence of 'keel bone fractures' in a flock indicates a high level of 'bone lesions' and therefore negative impact on welfare. In addition to the presence or absence of fractures, more severe fractures would generally indicate a more severe bone lesion.
Sensitivity and Specificity	The ABM is moderately sensitive because in the presence of bone lesion, the examination done by palpation might fail to identify some fractures. Unfortunately, the commonly used palpation method is by far the most feasible for assessment of live hens on farm. Sensitivity varies with the localisation of the fractures; at the cranial and medial parts of the bone, 75–93% of keel bone fractures are detected by palpation: (Wilkins et al., 2004; Buijs et al., 2019; Thøfner et al., 2021), but for fractures of the caudal part of the keel only 37% were detected by experienced assessors, (Buijs et al., 2019). This is especially relevant because in some cases as much as 96% of the fractures may occur in the caudal part (Thøfner et al., 2021). Radiographs, computed tomography and dissections of the keel bone are far more sensitive. Sensitivity and Specificity: The ABM is moderately sensitive because in the presence of bone lesion, the examination done by palpation might fail to identify some fractures. Unfortunately, the commonly used palpation method is by far the most feasible for assessment of live hens on farm. Sensitivity varies with the localisation of the fractures; at the cranial and medial parts of the bone, 75–93% of keel bone fractures are detected by palpation: (Wilkins et al., 2004; Buijs et al., 2019; Thøfner et al., 2021), but for fractures of the caudal part of the keel only 37% were detected by experienced assessors, (Buijs et al., 2019). This is especially relevant because in some cases as much as 96% of the fractures may occur in the caudal part (Thøfner et al., 2021). Radiographs, computed tomography and dissections of the keel bone are far more sensitive. Palpation can have moderate specificity (i.e. the percentage of keels without a fracture that were correctly classified as fracture-free varied between 54% (Wilkins et al., 2004) and 88% (Thøfner et al., 2021)). 'Keel bone fracture' (whatever the method is used to measure it) is of moderate specificity because if the bone lesion is absent, it is possible that keel bone fractures are wrongly identified.

Hazards and preventive and corrective measures

Although perches are a highly valued resource, they are also a hazard for keel bone damage in laying hens (Sandilands et al., 2009). This hazard has also been shown to be present in broiler breeders in a floor housing system with aerial perches and a multi-tier system with built-in perches (Gebhardt-Henrich et al., 2018). As found in laying hens, the design, e.g. distances and angles between perches or tiers can affect the accessibility to perches and aviary tiers with consequences for the frequency of unsuccessful jumps between levels (Scott et al., 1997; Stratmann et al., 2015). Different genetic lines in laying hens (Heerkens et al., 2016; Candelotto et al., 2017) and broiler breeders (Gebhardt-Henrich et al., 2018) differ in their prevalence of keel bone fractures. An abnormal bone metabolism (Wei et al., 2021) or diets deficient in calcium (Alm et al., 2017) or phosphorous (Wei et al., 2022) also increase the risk of keel bone fractures (Wei et al., 2021).

At the moment, no preventive measures for bone lesions are known for broiler breeders. Ramps can reduce keel bone damage in laying hens (Stratmann et al., 2015; Heerkens et al., 2016) but have not been investigated in broiler breeders. In laying hens, genetic selection for high bone strength has been suggested, but it is not clear if genetics or the different behaviour of the two broiler breeder hybrids tested in Gebhardt-Henrich et al. (2018) influenced keel bone fractures. Diets deficient in calcium or phosphorous should be avoided as the negative impact demonstrated in laying hens is also likely to occur in broiler breeders.

In most cases, keel bone fractures form callus material and heal within 4–8 weeks without intervention (Baur et al., 2020). Corrective measures on the level of the affected bird or flock are not possible.

3.4.2.3. Cold stress

Description of WC, category of bird and husbandry systems

'Cold stress' was identified as one of the highly relevant welfare consequences for day-old chicks hatched in hatchery and for chickens for meat production kept in mobile systems with free range (Table 5).

The animal experiences stress and/or negative affective states such as discomfort and/or distress when exposed to effective temperatures below its thermal comfort zone. Birds exchange heat by conduction, convection, radiation and evaporation. Heat exchange via radiation can be a major contributor to cold stress. In very cold, clear weather significant heat can radiate to the sky. In cold conditions, air movement will increase convective heat loss as well as surface evaporative cooling in case birds are wetted. This will lead to cold stress.

In an experimental study in which ambient temperatures were decreased stepwise in a climate chamber the rectal temperature (Tr) of broilers aged 30–32 days became significantly lower between 8°C and 14°C compared with values at 26°C (Koh et al., 2000). An experimental study in which ambient temperatures were decreased stepwise in a climate chamber (Koh et al., 2000) revealed that the rectal temperature (Tr) of broilers aged 30–32 days decreased with declining ambient temperature, becoming significantly lower between 8°C and 14°C compared with values at 26°C (Koh et al., 2000).

When the effective temperature, which is a combination of temperature, humidity and air speed, is too low, the thermoregulatory capacity of the birds for homoeothermy is exceeded. Birds can die from hypothermia if the conditions are too cold, or the birds are wet and cold (Caffrey et al., 2017).

The thermoneutral zone is defined as 'the range of ambient temperature within which metabolic rate is at a minimum, and within which temperature regulation is achieved by non-evaporative physical processes alone' (Nielsen et al., 2020), see Figure 13. Many factors influence the thermoneutral zone including feather cover, size, body condition score, hybrid, nutritional level, agitation level and environmental factors such as heat loss to the floor, humidity, air velocity around the animal, ambient air temperature, but also motor activity (Pereira and Nääs, 2008; Bracke et al., 2020).

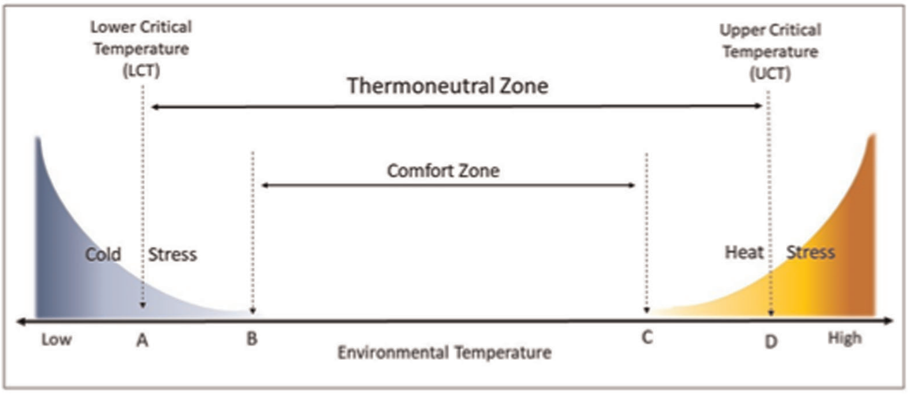


Figure 13: Schematic representation of thermal zones as a function of the environmental temperature (From EFSA AHAW Panel (2022a))

Young chickens behave in the first days as poikilotherm, which means that they are dependent on the external conditions to keep their body temperature at the desired level (Nichelmann and Tzschentke, 2002). Appropriate effective temperature (Nielsen et al., 2020) is therefore required to keep the body temperature of chickens at the desired level (40–41°C) (Mujahid and Furuse, 2009; Maman et al., 2019). If the body temperature of a chicken drops, it will become inactive (lethargic) and lie down which further accelerates the undercooling (Mujahid and Furuse, 2009). Chickens that are too cold will clump together and are less likely to go to feed and water, which will lead to dehydration and starvation. In addition, these chickens will also be more susceptible to infections, and with prolonged exposure, the result is increased risk of mortality, particularly during the first week of age (Heier et al., 2002). Older chickens that can regulate their body temperature may still suffer from cold stress when, e.g. housed outdoors during winter. Regardless of age, chickens experiencing cold stress will show huddling to reduce temperature loss and the cloacal temperature will drop below the normal range. Young chicks may emit distress calls. With very cold temperatures there is a risk for frost bites on the comb (Forkman et al., 2004).

For slower-growing chickens, as an example, the temperatures recommended for Hubbard Premium chickens are around 30°C (40–60% humidity) at placement to 19–21°C (50–70% humidity) at 42 days of age and older (management guide Hubbard (2022)), and for older broilers with outdoor range (Label Rouge) indoor temperatures of 18–24°C are advised (ERPA, no date), which should be in the comfort zone (Figure 13). For fast-growing chickens, the lower ranges for older chickens (> 27 days of age) are between 17°C and 21°C (Aviagen, 2018a; Cobb, 2021). The required temperature decreases with age of the chickens since the more they grow, the more heat they produce by their high metabolism. Therefore, the ambient temperature has to decrease to allow them to maintain their body temperature between 40°C and 41°C. Young chickens start to experience cold stress when the environmental temperature is below 30°C and they have major difficulties in controlling their body temperature under cold exposure (Yahav et al., 2009). As an example, chickens older than 5 days could keep their body temperature at the normal level with one hour exposure to 20°C and one hour exposure to 10°C, after which exposure the temperature increased to normal level, but younger chickens showed a significant drop in body temperature (Wekstein and Zolman, 1971). Shinder et al. (2007) found that broiler chickens of 3 and 4 days old exposed to temperatures of 10°C and 15°C for 180 min recovered their surface temperature to normal values when exposed to the thermos-comfort temperature again, illustrating that the period of exposure is important, and that recovery is possible when the temperature is not too low and with relative short exposure duration. Young chicks may show acclimatisation to cold exposure as with repeated exposure to cold they improved the ability to control their body temperature (Shinder et al., 2007; Yahav et al., 2009). There is very limited to no information available when older broilers start to experience cold stress. The negative effect of acute cold exposure in adult broiler chickens is generally limited to the lower range of the thermal neutral zone, because of the massive insulation provided by skin fat and the feather cover in older broilers, along with the small surface-to-volume ratio. In addition, also older chickens show acclimatisation to cold temperatures with repeated exposure (Yahav et al., 2009).

The duration, prevalence and severity depend on the category of bird under consideration. The duration of cold stress in young chicks may vary from less than one hour to a few hours (e.g. only experienced during handling) to several days when the appropriate climate is not (continuously) provided in the first days of life in the broiler house (Heier et al., 2002). The prevalence and severity may also vary widely. For example, not only certain rooms in the hatchery area in the broiler house may be affected, but also all chickens when waiting in a too cold environment before transport. Regarding the housing climate in the first week of life, farmers need to carefully and frequently observe the flock (using appropriate ABMs) and adjust the climate if needed. Severity may also vary, but it may have severe consequences and result in mortality if it lasts too long.

Regarding older chickens, cold stress only occurs in some housing systems with outdoor access in cold seasons. The prevalence may be low and restricted to specific cold periods in a year and only affect part of a flock being outside for too long. Duration is dependent on exposure time, but chickens can usually go inside which limits duration. Severity is much less as compared to day-old chicks as it usually does not result in mortality or increased susceptibility to disease, although frostbite on the comb may happen with very cold temperatures.

Description, measurement, interpretation and characteristics of ABMs

'Huddling', 'cloacal temperature', 'surface temperature', 'lethargy' (see Section 3.4.2.21), 'mortality' (Section 3.4.2.21), 'distress calls' (Section 3.4.2.21) are ABMs for 'cold stress'. 'Huddling', 'cloacal temperature' and 'lethargy' are ABMs for 'cold stress' for both day-old chicks and broiler chickens. The other ABMs ('surface temperature', 'mortality' and 'distress calls') are for 'cold stress' in only day-old chicks.

Huddling

Definition	Chickens are grouping together into tight groups, sitting closely alongside each other, often in 'clumps' with areas of empty space in between, which is distinct from normal 'loose grouping' that chickens show when resting (Welfare Quality®, 2009).
Measurement	Observation of the proportion of chickens showing huddling behaviour (Welfare Quality®, 2009).
Interpretation	Chickens huddle (clumping together in tight groups) to reduce heat loss as an attempt to maintain their body temperature within the normal range. The proportion of chickens showing huddling in the flock is used as indicator for the extent of cold stress, with more cold stress present with more chickens showing huddling (Welfare Quality®, 2009). Piling up or gathering in a corner following a fearful stimulus is not huddling.
Sensitivity and Specificity	The ABM is highly sensitive: chickens will clump together as a response to low environmental temperatures; in case of cold stress, it is likely that chickens huddle (Welfare Quality®, 2009).

	The measure is highly specific: when the chickens are not experiencing cold stress, they may also group but these groups are looser with empty spaces in between the chickens, and the behaviour differs in that sense from huddling behaviour (Welfare Quality®, 2009).

Cloacal temperature

Definition	Core body temperature measured in the cloaca of the chicken (Mujahid and Furuse, 2009).
Measurement	Measuring cloacal temperature using a thermometer in a representative sample of chickens.
Interpretation	A body temperature lower than 40°C indicates that chickens are too cold (Mujahid and Furuse, 2009; Maman et al., 2019).
Sensitivity and Specificity	The measure has high sensitivity for day-old chicks. When day-old chicks are too cold, the cloacal temperature decreases. For older chickens that can regulate their body temperature, the measure has moderate sensitivity, as these birds may not experience a drop in cloacal temperature before prolonged exposure to cold stress. The measure is highly specific. When chickens are not experiencing cold stress, they do not have a cloacal temperature below 40°C.

Surface temperature

Definition	Temperature measured on the surface of the day-old chick (wing, head, leg, back) (Vieira et al., 2016).
Measurement	Measuring surface temperature using an infrared thermometer on wing, head, leg and back of each chick to calculate an average temperature per chick (equation for calculation is available in Vieira et al. (2016)).
Interpretation	A surface temperature lower than 34°C indicates that the chickens are too cold (Vieira et al., 2016).
Sensitivity and Specificity	The ABM has high sensitivity. When chicks are too cold, the surface temperature decreases. The ABM has high specificity. When the chickens are not experiencing cold stress, the surface temperature of the chick is above 34°C.

Hazards and preventive and corrective measures

Day-old chicks hatched in hatchery

Too low effective temperature is the main hazard responsible for cold stress (Maman et al., 2019; Vieira et al., 2019). For day- old chicks, the temperature is too low if it is below 30°C.

This too low temperature can occur in the holding room in the hatchery, before loading on the trucks, during transport (EFSA AHAW Panel, 2022a) and during the first days on the broiler farm. Cold stress can occur in the holding room or on the farm due to failure of the heating system, or when the room or broiler house is insufficiently heated. In addition, when the chickens are spray-vaccinated but cannot dry before transport this may cause cold stress, although no scientific literature on this has been found (Lambrecht et al., 2020).

To prevent cold stress in day-old chicks in the hatchery, the temperature in the storage room should be kept at 30–35°C (EFSA AHAW Panel, 2022a). Drying of chicks after hatching or spray vaccination is also a prerequisite for avoiding chicks staying wet and being exposed to too low effective temperature. Upon arrival on the broiler farm, pre-heating of the barn and controlling ventilation to get the appropriate environmental temperature (30–35°C) upon placement and during the first days of life is essential to prevent cold stress (Karcher, 2021; Yerpes et al., 2020, 2021). Alternatively, dark brooders or brooding rings can be used with a temperature of 32–35°C at the edge of the dark brooder as heating source (Aviagen, 2018a).

Corrective actions are to increase temperature/reduce ventilation when the body temperature of the chickens drops below 40°C, both in the holding room of the hatchery and in the barn, or, to move the chickens to a warmer place if the holding room is too cold.

Broiler chickens in mobile systems with free range

Non-heated, poorly ventilated mobile houses, which might also be located in an unfavourable place (lacking sunshine, etc.), are the largest hazard for cold stress in broilers in mobile systems. Cold temperatures, especially indoor, might be caused by a non-solid floor lacking isolation, draught and/or no or insufficiently equipped heat sources.

To prevent cold stress in chickens in mobile systems, sufficient heat sources should be present in mobile houses to keep the environmental temperature according to the required profile as defined for the various breeds (e.g. Aviagen, 2018a). Draught should be prevented, and sufficient bedding should be present on the floor for isolation.

If chickens are too cold, e.g. shown by huddling behaviour, the environmental temperature should be increased. In case of draught, the ventilation should be checked and adjusted.

3.4.2.4. Inability to perform comfort behaviour

Description of WC, category of bird and husbandry systems

'Inability to perform comfort behaviour' was identified by the working group experts as a highly relevant welfare consequence for Chickens for meat production kept in floor systems, Broiler breeders kept in individual cages and in collective cages. A general definition of 'inability to perform comfort behaviour' is given in Table 5.

Comfort behaviour involves behaviours performed to maintain the feather cover clean and in a good condition and includes dustbathing, preening, ruffling, arranging feathers and wing stretching and wing flapping (Kim et al., 2014; Sultana et al., 2020). Dustbathing consists of a series of behavioural elements where a substrate is brought into and distributed between the feathers and ends with feather shaking through which dust is removed from the feather cover. It has been shown to develop in chicks at an age of 1 week. A typical dustbathing bout lasts for 20–30 min (Baxter et al., 2019). An appropriate dustbathing substrate is a dry and loose substrate consisting of small particles (van Liere, 1992). Studies comparing different types of litter material have shown that laying hens prefer litter material with a small particle size that can go between the feathers, such as that of sand (Sanotra et al., 1995) and peat (Vestergaard and Baranyiova, 1996; de Jong et al., 2007). Depending on the type of sand, the particle size can vary from < 0.03 mm in fine sand up to 2 mm for coarse sand. Particles in peat vary in size from < 0.03 mm up to 7 mm, since it often contains small wooden sticks. A meta-analysis also supported the preference for these two substrates (Monckton et al., 2020a) but the size of the particles was not significant in this analysis. However, the authors point out that only three of ten studies reported the particle sizes for any of the substrates used and none reported particle size for all substrates. Thus, this lack of a significant results here cannot be interpreted to mean that particle size is unimportant. Both sand and peat resemble soil, the natural substrate material for birds. Soil is usually considered to range from clay or silt, which have very small particle sizes of 0.002 mm up to coarse sand, but it can also contain larger stones. Preferences for sand and peat are apparent from an early age in laying hen chicks (Skånberg et al., 2021). In this study only the particle size for the sand was given (< 0.03 mm). Taken together literature indicates that a good dustbathing substrate contains small particles. In addition to the litter being dry and having small particles, studies have also shown that birds prefer dustbathing in substrates with a low lipid content (e.g. Shields et al., 2004; Scholz et al., 2011; Guinebretière et al., 2014).

When litter is missing completely or if litter is too wet or caked, the birds will not be able to perform functional dustbathing behaviour (fulfilling cleaning purpose), or sham dustbathing is observed. Preening consists of the typical stroking and nibbling of the feathers with the beak and may be accompanied by pecking the own feathers to remove particles (Van Liere, 1991). It is often performed on elevated areas and is affected by the shape of the perch (Skånberg et al., 2021). Chickens will perform feather ruffling and shaking movements of the whole body to rearrange feathers. In addition to the preservation of the intact feather coat, the comfort behaviour is also likely to be associated with relaxation (Zimmerman et al., 2011). Chickens will stretch and flap their wings before continuing, e.g. exploratory behaviours. The behaviour is usually influenced by the circadian rhythm of the broiler as well as socially facilitated resulting in a synchronisation of behaviours across the flock (Grebey et al., 2020).

During the whole life of a chicken, comfort behaviour will remain among the most important behaviours. However, the period of life during which the individual is prevented from performing a specific comfort behaviour (e.g. dustbathing is compromised) may vary between the different types of comfort behaviours and it may be prevented for different reasons. Typically, broiler chickens reared on the floor might be unable to perform comfort behaviours especially later in life due to decreasing litter quality and space per individual. Caged broiler breeders will not have access to litter and therefore will never be able to perform dustbathing and the low height does not allow wing flapping. The severity of lacking possibilities to exhibit comfort behaviour is high and leads not only to the absence of comfort behaviour but might also be expressed as sham or stereotypic behaviours. The prevalence of the welfare consequence is high as the major factors for comfort behaviours are good litter quality (loose substrate with small particles) as well as sufficient space per bird, which are both challenged by the high stocking densities commonly applied in floor and caged housing.

Wing flapping is especially frequent in adult males and is related to dominance behaviour (Jones and Mench, 1991) and a general indicator of arousal (Jonaidi et al., 2003). Wing flapping is shown in different contexts ranging from comfort behaviour to an indicator of stress. In young chickens until about 10 weeks of age, playful behaviour includes the element wing flapping (Dawson and Siegel, 1967; Liu et al., 2020). The frequency of wing flapping within the context of play reduces with age. Wing flapping is shown more frequently in chickens in semi-intensive and free-range systems, than in the more intensive housing systems with high stocking densities (Mench et al., 2001; Ahmad et al., 2021). Wing flapping in mature roosters has been interpreted as courtship and/or territorial behaviour (McGary et al., 2003) and can be a general indicator of arousal (Jonaidi et al., 2003). Less positively, wing flapping is considered a stress-induced behaviour (Wolff et al., 2019).

Wing flapping therefore potentially has three different meanings: play behaviour before maturity, arousal after maturity, as well as being a comfort behaviour.

Description, measurement, interpretation and characteristics of ABMs

Related ABMs for 'inability to perform comfort behaviour' are 'dustbathing', 'preening', 'wing and leg stretching', 'wing flapping', and the iceberg indicator 'feather and body dirtiness' (see Section 3.4.2.21).

Dustbathing

'Dustbathing' is an ABM for broilers kept in floor systems, broiler breeders kept in individual and collective cages.

Definition	A sequence of movements that starts when a bird lies down and tosses loose material onto and between the feathers. Other activities may occur in variable sequence during a dustbathing bout, including side lying, scratching, bill raking, head and body rubbing. A dustbathing bout usually ends with body shaking which removes dust from the plumage (Bach et al., 2019).
Measurement	The number of dustbathing birds can be assessed quantitatively by direct observations or video. The number of birds (or proportion of birds) dustbathing either at a precise moment (scan) or during an observation period can be reported. The behaviour is a specific sequence of movements and includes the presence of dustbathing material on/in the plumage. The sequence is completed when the chicken stands up and shakes the material off. Only complete dustbathing should be specified as such, in contrast to sham dustbathing (dustbathing on a non-littered floor) or interrupted sequences (chickens being disturbed by another chicken or not completing the whole sequence). Counting the number of chickens showing dustbathing does not indicate if the whole sequence could be completed. Incomplete dustbathing and sham dustbathing should be recorded separately. Video recordings or long observations are needed to determine whether the whole dustbathing sequence is completed, and these are not usually feasible. Automation should be supported in terms of deep learning mechanisms extracting the occurrence of the ABM from video recordings.
Interpretation	Dustbathing is an essential behavioural need of the chicken to maintain the feather cover in a good condition. A high proportion of dustbathing occasions when a bird starts dustbathing, but then stops or is interrupted before the whole dustbathing sequence is complete, indicates suboptimal conditions such as suboptimal or absence of substrate (Larsen et al., 2000), lack of space or protection (Louton et al., 2016). Sham dustbathing is performed in the absence of substrate (Olsson et al., 2002). There are intrinsic (e.g. preening), as well as extrinsic factors (such as sunlight) as well as social facilitation which trigger dustbathing, in addition to the circadian rhythm of the chicken. The more 'dustbathing' is performed by the chicken, the better the ability to perform comfort behaviour.

Sensitivity and Specificity	The measure has high sensitivity: in case of absence of conditions to perform dustbathing, the complete sequence of dustbathing behaviour cannot be observed, and only single components or sham dustbathing might occur. Therefore, in case of inability to perform comfort behaviour, it will be reflected by diminished dustbathing or performance of incomplete sequences. The measure has high specificity: chickens will complete the full dustbathing sequence when the conditions are present (sufficient space, appropriate litter) and therefore animals will perform dustbathing when inability to perform comfort behaviour is absent.

Preening

'Preening' is an ABM for broiler chickens kept in floor systems and broiler breeders kept in individual and collective cages

Definition	'Preening' involves raising the feathers to clean and realign them with the beak. The broiler directs its beak to its own plumage of several body parts (thorax, abdomen, shoulder, interior and exterior wings, rumps, back, and cloaca) and carries on pecking, nibbling, combing or rotating movements, once or repeatedly (Zhao et al., 2014). During the process, lubrication from the preen gland is distributed to the feathers.
Measurement	Directly observable: numbers of broilers performing preening behaviour. Recording: e.g. observable from video recordings: number of animals preening either at a precise moment (scan sampling) or during an observation period in an area of known size (Lee and Chen, 2007; Alvino et al., 2009). As for most behaviours, a circadian rhythm and social facilitation might be applicable, in this case, with increased preening observed in the mornings (Zhao et al., 2014).
Interpretation	Preening behaviour is affected by space availability, tending to occur at lower frequency or duration when space is limited (Hall, 2001; Buijs et al., 2010, 2011). The lower the space allowance, the lower the frequency of preening (Hall, 2001; Buijs et al., 2010, 2011). Birds preen more when the light intensity is higher and when the difference in light intensity between the dark and light period is reduced the circadian rhythm become less pronounced (Alvino et al., 2009). Preening behaviour is affected by space availability, tending to occur at lower frequency or duration when space is limited (Hall, 2001; Buijs et al., 2010, 2011). The lower the space allowance, the lower the frequency of preening (Hall, 2001; Buijs et al., 2010, 2011). Birds preen more when the light intensity is higher and when the difference in light intensity between the dark and light period is reduced the circadian rhythm become less pronounced (Alvino et al., 2009).
Sensitivity and Specificity	Preening measurement is moderately sensitive. If broilers cannot perform other comfort behaviour, they may increase preening as a displacement behaviour. Therefore, in case the welfare consequence is present, it might not be always detected by a change in preening behaviour. Preening measurement is of low specificity. If the ability to perform comfort behaviour is not limited, preening can nevertheless be impacted by other parameters, like light intensity, day length and bedding type (Alvino et al., 2009; Schwean-Lardner et al., 2012).

Wing and leg stretching

'Wing and leg stretching' is an ABM for chickens kept in floor systems, broiler breeders in individual and collective cages.

Definition	The chicken spreads one leg, or both leg and wing on the same side of the body sideward or unilaterally back- and downward (Li et al., 2021a). The bird may be sitting or standing while stretching (Pichova et al., 2016).
Measurement	Directly observable: numbers of wing and leg stretches recorded in a sample of time observation with direct observations. Methods such as classical ethogram by focal animal or behavioural sampling or scan sampling techniques might be applied. Also deep learning mechanisms for the detection of the behaviour in videos might be applicable (Li et al., 2021a). This behaviour is in any case happening from time to time and very brief, therefore requires a certain time to be observed (e.g. focal sampling, video recording) (Vestergaard et al., 1997).This behaviour is in any case happening from time to time and very brief,

	therefore requires a certain time to be observed (e.g. focal sampling, video recording) (Vestergaard et al., 1997)
Interpretation	Lack of occurrence of wing and leg stretching indicates lack of sufficient space to perform the behaviour and therefore the existence of the welfare consequence. Sometimes an attempt of wing or leg stretching can be observed without achieving a full stretching position because of lack of space (Buijs et al., 2011).
Sensitivity and Specificity	'Wing and leg stretching' is considered moderately sensitive since when the inability to perform comfort behaviour is present, it is likely that wing and leg stretching occurrence will be reduced. 'Wing and leg stretching' is considered as highly specific as when ability to perform comfort behaviour is not limited, then wing and leg stretching occurrence will not be impacted.

Wing flapping

'Wing flapping' is an ABM for chickens kept in floor systems, broiler breeders in individual and collective cages.

Definition	Bilateral rapid upward and downward movement of the wings performed while standing still (Sokołowicz et al., 2020).
Measurement	Directly observable: numbers of wing flapping events recorded in a predefined observation period, with direct observation of a cage or part of the cage or a predefined area in the house for chickens for meat production kept in floor systems. Observable with video of a cage or part of the cage: number of wing flapping events during an observation period. For comparison, frequency of occurrences must be standardised by unit of time and number of birds observed. This behaviour is in any case happening from time to time and very brief, therefore a sufficiently long observation time is needed (e.g. focal sampling, *ad libitum*).
Interpretation	With increasing space restriction, broiler chickens or broiler breeders will perform less wing flapping behaviour.
Sensitivity and Specificity	The behaviour is highly sensitive, as when there is inability to perform comfort behaviour, the chicken will perform less 'wing flapping'. 'Wing flapping' has low specificity. If comfort behaviour can be performed, 'wing flapping' can also be affected by other factors such as the restriction of movement.

Broiler chickens in floor systems

The proportion of broiler chickens showing undisturbed and complete dustbathing behaviour (van Liere et al., 1990; van Liere, 1992) and the proportion of broiler chickens showing undisturbed preening and stretching behaviour indicate the ability to perform comfort behaviour. Repeating certain phases of dustbathing but not completing the behaviour (van Liere, 1992) or a short duration of dustbathing (van Liere, 1992) may indicate that the environment is not appropriate for dustbathing (Baxter et al., 2018a). In addition to live observations or video, automated video-based analysis is being developed (Fang et al., 2021).

Broiler breeders kept in individual unfurnished cages

In unfurnished cages, the bird will not be able to show normal dustbathing behaviour, but only sham dustbathing. Preening behaviour may also be affected as it is often performed on a perch.

Broiler breeders kept in collective cages

The main comfort behaviours that may be restricted in furnished cages are dustbathing, preening and wing and leg stretching. Sham dustbathing shows that furnished cages do not fulfil the needs of chickens regarding dustbathing (Merrill and Nicol, 2005). In collective cages, there is more space to perform wing flapping and stretching compared with individual cages. However, hardly any litter is available so almost all dustbathing that is performed is sham dustbathing without substrate.

Hazards and preventive and corrective measures

Broiler chickens in floor systems

The performance of dustbathing and preening behaviour can be disturbed by other chickens moving through a group of chickens performing comfort behaviours (Buijs et al., 2011). Therefore, stocking density has a major influence on the ability to perform undisturbed comfort behaviour including wing and leg stretching (Meluzzi and Sirri, 2009). In addition, the broiler needs appropriate litter to perform dustbathing (dry, loose, small particle size) as explained above (Zikic et al., 2017; Baxter et al., 2018b). Dustbathing is suggested to be stimulated by sunlight (Duncan et al., 1998). Other environmental factors such as inappropriate lighting management (Lucena et al., 2020), along with other factors leading to decreased health status (Abeyesinghe et al., 2021) of the individual will display the major hazards for this behavioural trait. Ongoing scientific work addresses the optimisation of the light intensity and light colour, or which combination supports the behaviour of the animals (Blatchford et al., 2012; Huth and Archer, 2015). Therefore, an inappropriate lighting program is considered a hazard for chicken performing comfort behaviour as it is socially facilitated to increase behavioural synchronicity (Alvino et al., 2009). This behavioural synchronicity is influenced by undisturbed resting (light: dark ratio) as well as the intensity of the light provided (increased at 200 lux/daylight).

Comfort behaviour is highly correlated with appropriate stocking densities, which indirectly contribute to the litter quality and space allowance of an individual to perform stretching, dustbathing, etc. Therefore, a preventive measure will be to provide dry and friable litter from day one onwards and ensure that the litter will stay in the same condition until the end of rearing (Pepper and Dunlop, 2021). As stated in legislative acts across Europe, e.g. Germany, 'all broilers should have constant access to dry, loose litter suitable for pecking, scratching and dustbathing'.[12] In addition, the choice of substrate and the location, e.g. dustbathing troughs, are stimulating this behaviour. Exemplary automatic systems have already been developed to promote the supply of loose, fresh bedding or occupational material (Baxter et al., 2018a; Vasdal et al., 2018), and are currently being transferred into widespread practice (Schmidt et al., 2019). This can be reached by careful management of watering system (to avoid leaking), of appropriate ventilation, and by re-littering when needed. Appropriate stocking densities (Gholami et al., 2020) in combination with appropriate litter and housing management will support broiler welfare by allowing the performance of comfort behaviour (Pepper and Dunlop, 2021). Also thinning should be considered as prevention as it reduces stocking density and increases space allowance during a given rearing period (Tuyttens et al., 2014). Re-littering may consist of partial replacement of litter or adding additional litter. Mitigation can also be reached by adding substrate for dustbathing in specific areas such as dustbathing troughs with a low entry. Adding elevated platforms can help to reduce the stocking density. Supporting the chicken to perform comfort behaviour will predominantly be driven by space allowance and litter quality. Therefore, corrective measures are lowering stocking density and re-littering within the production period.

Broiler breeders in individual and collective cages

The main hazard for breeding birds in individual unfurnished cages are the lack of suitable friable litter material and, to a lesser extent, the lack of a perch. The height of the cage will limit wing stretching and especially wing flapping. Broiler breeder females that were raised on litter showed less stereotypic pecking at the feeder, wall and other birds than the birds raised on a slatted floor. Tonic immobility was greater and plasma corticosterone levels were lower when litter was provided (Hocking et al., 2005). Broiler breeders use perches and elevated structures during rearing and laying (Gebhardt-Henrich et al., 2017b; Gebhardt-Henrich et al., 2018). Perching is a behavioural need for chickens especially during the night (Olsson and Keeling, 2000; Schrader and Müller, 2009) and preening is also performed while a bird is perching (e.g. Duncan et al., 1992; Pickel et al., 2010).

The main hazards for breeding birds in collective cages is the lack of suitable substrates for dustbathing inhibits birds to display this highly valued behaviour. Depending on the design of the furnished cage, the space or stocking density may also affect the ability of birds to show comfort behaviour. Inappropriate lighting may also be a hazard.

[12] Ordinance on the Protection of Farm Animals and Other Animals Kept for the Production of Animal Products during Husbandry (Tierschutz-Nutztierhaltungsverordnung - TierSchNutztV).

Preventive measures

In broiler breeders kept in individual cages providing appropriate litter material, sufficient space and perches would make it more likely that birds would be able to perform comfort behaviour. Given that it is no longer allowed to keep laying hens in unfurnished cages in the EU (Council Directive 1999/74/EC[2]), it seems inconsistent not to require that adult broiler breeders also have access to perches and litter to allow them to perform comfort behaviours, since they would also need to have access to this resource.

In broiler breeders in collective cages, furnishing the cages with nests, elevated perches, and substrate for dustbathing can improve welfare conditions for caged broiler breeders to a certain extent (extensive literature on laying hens (e.g. Shimmura et al., 2007)). Reducing stocking density can also give birds more space to perform comfort behaviours.

Corrective and mitigative measures

In broiler breeders kept in individual cages, it is difficult to imagine a corrective measure since the ability to perform comfort behaviours is dependent on the presence of the appropriate resources and sufficient space. If individual cages are used the time that birds are kept in them should be kept to a minimum.

In broiler breeders kept in collective cages, reducing the number of birds in the cage, as well as changing the litter or adding new litter to keep it in a good quality can result in more comfort behaviour being performed.

3.4.2.5. Inability to perform exploratory or foraging behaviour

Description of WC, category of bird and husbandry systems

'Inability to perform exploratory or foraging behaviour' was identified by the working group as a highly relevant welfare consequence for chickens for meat production kept in floor systems, broiler breeders kept in individual cages and collective cages.

A general definition of 'inability to perform exploratory or foraging behaviour' is given in Table 5. Exploratory and foraging behaviour will be found in broilers along their whole life. Exploration is defined as the animal's gathering of environmental information by active moving. In case of the exploratory search for food, the behaviour is called foraging (Abeyesinghe et al., 2021). Foraging is predominantly directed towards the litter and therefore depends on its quality (Campbell et al., 2017). Normally, food will be allocated along fixed food lines. Nevertheless, within the chicken's normal daily behaviour, a large proportion of time (ranging from 7% in high performing broilers to 70% in layers) (Castellini et al., 2016) will be spent by exploring and foraging. Fear is hampering foraging (Meuser et al., 2021) and that is why exploratory and foraging behaviour is a reliable welfare indicator. A lack or inability of opportunity to perform this intrinsic motivation results in frustration/boredom and favours abnormal behaviour such as (injurious) feather pecking and cannibalism. The frequency for exploratory and foraging behaviour might be influenced by genetics and husbandry systems (Yan et al., 2021), part of the animal's personality (Garnham and Løvlie, 2018) and range use (Ferreira et al., 2021). In addition, environmental enrichment including litter substrate (Monckton et al., 2020a) and other objects, higher space allowance (Bach et al., 2019) and (elevated) structures (Dawson et al., 2021) will promote exploration and foraging behaviour (Riber et al., 2018). Active exploratory and foraging behaviour in turn supports the locomotor and health status of the broilers. Broiler genetic and feeding management (Dixon et al., 2014; Pichova et al., 2016) supporting a welfare-oriented growth, and environmental interaction (Trocino et al., 2020) will be spent by exploring and foraging. The motivational state to explore or forage is not reduced when food is offered *ad libitum* (Dawkins, 1989).

Along the bird's life, exploration and foraging decreases over time due to an increasing weight.

In general, due to high stocking densities, barren environments (individual and collective cages) and heavy broiler lines, the prevalence of this welfare consequence is high. 'Inability to perform exploratory and foraging behaviour' is more prevalent and severe in broiler breeders kept in individual and collective cages compared to broiler chickens kept in the floor systems.

Description, measurement, interpretation and characteristics of ABMs

'Walking, scratching and pecking' as part of foraging and exploratory behaviour, and the iceberg indicators 'injurious pecking' and 'plumage damage' (see Section 3.4.2.21) are ABMs for measuring the 'inability to perform exploratory and foraging behaviour'. 'Stereotypic behaviour' is an ABM for this welfare consequence in broiler breeders kept in cages (see Section 3.4.2.21)

Walking, scratching and pecking

Definition	In relation to walking, scratching and pecking animals explore with its beak (Shimmura et al., 2008) to obtain information of their environment, or in case of foraging, to investigate food or other eatable materials. To do so, chickens show a behaviour that is composed of locomotory bouts, specifically walking, and/or scratching on the floor, and pecking at the litter, floor or other objects. This action is often repeated several times in a row (Moe et al., 2014, adapted from 'foraging'). Pecking might be interrupted by scratching episodes when directed toward the litter (de Jong and Gunnink, 2019). The chicken moves litter substrate by its feet as part of foraging behaviour (Pichova et al., 2016). Foraging and exploration are species-specific behaviours that may cause abnormal behaviour if the chicken is not able to perform it (Abeyesinghe et al., 2021). 'Walking, scratching and pecking' does not include feed intake or pecking at conspecifics or scratching shown by hens in the nest prior to egg laying (Vasdal et al., 2019b) or prior to dustbathing (Pichova et al., 2016).
Measurement	In general, the assessment is usually done by scan sampling (Daigle and Siegford, 2014), or focal animals or behaviour sampling. The rate of complete foraging bouts is given by the number of birds exhibiting exploration or foraging behaviour out of the total of active birds (Bach et al., 2019) during scan sampling. The less animals walk, scratch and/or peck the physical environment, the higher level of the 'inability to perform exploratory or foraging behaviour'. Usually, broilers will be observed by video and exploration as well as foraging will be quantified using scan sampling methods (Daigle and Siegford, 2014). The measurement of foraging behaviour is not part of regular welfare assessments such as Welfare Quality®, but often exploratory behaviours are covered. In the Welfare Quality® Assessment Protocol for poultry it is described in the laying hen part and can easily be adapted to broilers. Stereotypic behaviours such as spot pecking and feather pecking might indicate frustration due to the lack of possibility to exhibit exploratory and foraging behaviours. Exploratory behaviour can be assessed using the Novel Object test (Tahamtani and Riber, 2020; Meuser et al., 2021).
Interpretation	The less animals walk, scratch and peck the physical environment, the more the inability to perform exploratory or foraging behaviour there is.
Sensitivity and Specificity	The sensitivity of the ABM 'walking, scratching and pecking' is high as when there is inability to perform foraging behaviour the occurrence of walking/scratching/pecking will decrease or disappear. The ABM is moderately specific for broiler breeders in floor. If the ability to perform exploratory or foraging behaviour is not limited, the walking/scratching/pecking expression can still be impacted. For instance, walking can also be impacted by other factors (e.g. animal stocking density, locomotory disorders). However, in broiler breeders in individual housing, is difficult to assess since the welfare consequence will never be absent in individual cage with friable substrate.

Breeders in cages

In feed restricted broiler breeders, kept in individual and collective cages, an increased foraging behaviour is seen probably reflecting their increased hunger. Therefore, it can be expected that in broiler breeders kept in cages, where birds are both feed restricted and the possibilities to forage are limited because of lack of litter, there is a greater negative effect on welfare. Therefore, being unable to show exploratory and foraging behaviour can lead to the development of the stereotypic behaviour of pacing.

Hazards and preventive and corrective measures

Broiler chickens in floor systems

High body weight, presence of FPD and too low space allowance per bird and lack of enrichment influence the exploratory and foraging behaviour. The walking ability of the chicken, the space allowance and an environment offering material to perform foraging and exploratory behaviours should be the focus. This implies mainly the quality of the litter and entails the absence of clumped, caked or inappropriate litter substrates as well as the absence of barren environments lacking environmental enrichment (e.g. objects to be explored). Birds with high weights, reduced integument strength or general health constraints will not be mobile and, thus, will not be able to show active behaviours.

Depending on the hybrid it is difficult to tell whether the animals reduce these behaviours at an advanced age or whether they are unable to perform them due to extrinsic or intrinsic factors, such as space allowance, and body weight at the end of the rearing period. With high-performing hybrids (fast-growing broilers), it is likely that high daily weight gain will decrease the capacity of the animal to perform exploratory behaviours, and this will exacerbate with increasing age.

There are indications that feeding management influences exploratory and foraging behaviour (Tahamtani and Riber, 2020). Offering food enrichment could enhance foraging behaviour (Pichova et al., 2016). Whether scatter feeding will show long-term promotion is unclear so far (Wood et al., 2021). The provision of health supporting and environmental measures, e.g. platforms or other elevated structures, as well as an appropriate light regime, will promote exploratory and foraging behaviours. The use of elevated structures might not only facilitate the natural behaviour of the chickens but also improve the litter quality as natural behaviour and, in turn exploratory and foraging behaviour, prevents clumping of litter. Automatic provision of additional, new litter material will enhance exploratory behaviour.

The most practical and easiest way to correct a low level of exploration and foraging might be the provision of additional litter and/or straw bales that encourage the birds to exhibit foraging as well as exploratory behaviour (Riber et al., 2018). As exploratory behaviour requires space, thinning within the given production period might increase space allowance per bird enabling exploratory behaviours.

Broiler breeders in single and collective cages

Small cage size and lack of litter material makes exploratory and foraging behaviour in single cages almost impossible. In addition, there is insufficient space to add enrichment items that the bird could explore. A choice experiment with singly housed laying hens showed that hens choose to forage and explore litter areas when they have the opportunity (Hughes and Channing, 1998). Poor foot health due to inactivity and wire floors may contribute to the inability to move and perform exploratory behaviour. The total size and space of the enclosure, the stocking density and the inappropriate light management are hazards in broiler breeders kept in collective cages.

The provision of appropriate litter material for foraging is challenging in automated cage systems. Soft plastic mats like Astroturf are used in furnished cages for laying hens and might be an alternative to fully wired or slatted floors and may be used to provide at least feed to forage (Pokharel et al., 2018). However, feed cannot be used for dustbathing and disappears quickly. The use of feed as a scratching substance is also ethically questionable. Other resources like nest boxes and perches can be supplied in cages of a sufficient size. A larger size of cage would also prevent the insufficient space allowance to some extent.

It is difficult to define corrective measures since the ability to perform exploratory or foraging behaviours depends on the presence of the appropriate litter material which is usually absent in individual cages. If injurious pecking has developed as a result of the inability to perform exploratory and foraging behaviour, dimming the lights can reduce this behaviour. However, the welfare consequence may remain.

3.4.2.6. Gastro-enteric disorders and infectious diseases

Description of WC, category of bird and husbandry systems

'Gastro-enteric disorders (GED) and non gastro-enteric (Table 5 for definition) infectious diseases' were identified by working group experts as a highly relevant welfare consequence for broiler chickens kept in all husbandry systems (indoor floor systems with and without outdoor access and kept in mobile systems) during the whole rearing period.

The presence of GED may be due to a non-steady state of the microbiome and the intestinal tract leading to impaired welfare and performance in broiler chickens (Wickramasuriya et al., 2022). The gut health in poultry is considered as a holistic function of four major components: diet mucosa, microbiome and the immune system. Gastro-enteric disorders in broilers can also be caused by feed-borne toxins such mycotoxins (e.g. T-2 toxin) and biogenic amines (e.g. histamine, cadaverine, putrescine, spermine) causing injuries to the intestinal mucosa and malabsorption syndrome, respectively (Dekich, 1998).

Besides environmental and nutritional factors causing non-specific enteritis (dysbacteriosis and malabsorption) and dysfunction of the gut, there are many intestinal infections caused by bacteria (e.g. necrotic enteritis and colibacillosis), viruses (e.g. coronavirus, astrovirus, reovirus and haemorrhagic enteritis virus) and parasites (e.g. coccidiosis, blackhead caused by *Histomonas* *meleagridis*) that may cause dysbiosis and disturb the intestinal homeostasis. Necrotic enteritis caused by *Clostridium perfringens* results in high mortality, poor growth rate and lower feed conversion. Often the disease is triggered by changes in diets (e.g. increased proportion of barley, wheat in the feed) and coinfections with *Eimeria* spp. (Welfare Quality®, 2009).

Colibacillosis, caused by avian pathogenic E. coli in broilers, is characterised by lesions within the air sacs, the heart, and the liver, followed by septicaemia and death. Colibacillosis causes decreased performance, early (first week) morbidity and mortality (Guabiraba and Schouler, 2015; Fancher et al., 2021). Kemmett et al. (2014) reported an overall flock mortality (flock of 25,700 birds) at point of slaughter of 4.36% while flock mortality in the first week was recorded as 1.03% and 0.44% for the first 72 h. Overall, 37 birds collected within 72 h after placement were collected and subjected to post-mortem. Twenty-six out of 37 birds (70.27%) showed clinical signs associated with colibacillosis. Poor growth, performance and high mortality is also observed in broilers with coccidiosis after infection with *Eimeria*.

A longitudinal field study in the Netherlands (ter Veen et al., 2017) where 98 broiler flocks were weekly sampled showed the presence of different pathogens causing GED. Histopathological lesions indicative of intestinal disease were found in all flocks examined. The pathogens identified were chicken astrovirus (99% of flocks positive), avian nephritis virus 3 (100%), rotavirus A (95%), rotavirus D (52%), reovirus (100%), *Eimeria acervulina* (94%), *E. maxima* (49%) and *E. tenella* (40%).

Description, measurement, interpretation and characteristics of ABMs

Non-invasive and easy to measure ABMs for the GED are plumage/body cleanliness (see Section 3.4.2.21 on iceberg indicators), FPD (see Section 3.4.2.21), 'cloacal temperature' (temperature outside 40–41°C will need veterinary attention), 'lethargy' (see Section 3.4.2.21), 'impaired growth rate' (see Section 3.4.2.7 'prolonged hunger' the same ABM for broiler breeder is applicable for broiler chickens) and 'mortality' (see Section 3.4.2.21 on iceberg indicators). Inadequate digestion of feed by broilers due to dysbacteriosis, malabsorption and/or infection may have a negative effect on litter quality and in this way affect cleanliness of the birds and the incidence of contact dermatitis. Normally, birds keep their feathers clean to keep warm, and to protect themselves against dirt and skin infections. If feathers become wet or soiled with litter, faeces or dirt the feathers lose their functional role and so significantly impact the welfare of the bird. Enteritis often results in altered faecal state, decoloured faeces or increased liquid content due to diarrhoea, that downgrade litter quality inducing FPD. Increase of body temperature, often assessed by measuring the cloacal temperature in broilers, may be indicative for the presence of infectious diseases but also heat stress (Cândido et al., 2020). Lethargic birds – birds that do not move and have body posture with head down and ruffled feathers – are common signs in flocks with severe infections, such as coccidiosis. Dysbacteriosis, malabsorption and/or infection with pathogens will finally result in slower growth and even in mortality.

Hazards, preventive and corrective measures

Host factors (e.g. hybrid, sex, age), factors related to feed and feeding management (e.g. particle size, source, feed composition) and environmental factors (e.g. litter, stocking density, high effective temperature and biosecurity) affect overall the gut health in simultaneous manner and disturbance in any of these factors are intrinsically hazards leading to cause GED (Wickramasuriya et al., 2022). Commercial broiler lines like Ross, Cobb and Hubbard were mainly selected by growth performance criteria and often exhibit sub-optimal microbiota as compared to slower-growing chicken (Ocejo et al., 2019). In general, selection for growth tends to equip the birds with a higher capacity for high feed intake. It has been shown that both fast-growing breeds (i.e. commercial meat-type broiler chickens) and slower-growing birds have evidence of intestinal mucosal damage from *Campylobacter jenuni* although at a significantly different level (Humphrey et al., 2014). Fast-growing chicken breeds show a stronger inflammatory response that can lead to diarrhoea, which, in turn, leads to damage to the feet and legs on the birds due to standing on wet litter. Male broilers seem to have a resistance to innate coccidiosis compared to female broilers. The gut microbiota in broilers help to develop a mature immune response and that should be settled early in life (e.g. 3–4 days after hatching).

An important hazard for GED is inadequate feed and mainly feed processing (mash or pellets) and grinding (finely or coarsely) of the feed. In general, coarsely ground feed stimulates the gizzard function and consequently a better gut motility, longer digest retention time and enhanced production of digestive enzymes and nutrient transporters. Pellets, compared to mash feed, increase the growth of chickens via increased feed intake. In general, pellet-fed broilers show more beneficial bacteria (e.g.

increase in ileum of *coliform* bacteria and *enterococci* and reduced number of *C. perfringens* and *Lactobacilli* in the ceca) and volatile fatty acids in the gastrointestinal tract but seem to be more susceptible to *Salmonella* Typhimurium infections compared to mash-feed birds (Huang et al., 2006). Broiler diets leading to GED include those in which feed ingredients contain high quantities of non-starch polysaccharides (e.g. beta-glucans and arabinoxylans), omega-3 fatty acids (e.g. animal fats) as well as corn- and soybean meal. It is well known that non-starch polysaccharides lead to a viscous environment within the intestinal lumen resulting in sticky droppings and increased incidence of necrotic enteritis (M'Sadeq et al., 2015).

Three other important environmental hazards causing GED are stocking density, heat stress and lack of biosecurity measures in place. In a subclinical experimental challenge study with *C. perfringens*, it was shown that high stocking density (30 birds/m^2 vs 15 birds/m^2) affects unfavourably the welfare and gut health of broiler chicks and predisposes the birds to necrotic enteritis. This confirms the importance of stocking density as a management factor for the poultry industry (Tsiouris et al., 2015). Chickens with acute heat stress have higher mucosal damage, and heat stress is considered a predisposing factor for the development of subclinical necrotic enteritis in broiler chickens (Tsiouris et al., 2018). The implementation of biosecurity measures is commonly practiced in commercial broiler farming and entails training of farm staff, wearing protective clothes, providing the appropriate housing equipment, monitoring mortality and collecting dead birds, controlling entry and exit procedures and disinfecting the facilities between two flocks. Enhanced biosecurity at the farm level greatly reduced the colonisation of *Campylobacter* spp. (Georgiev et al., 2017). There seems to be high impact of farm environment on the poultry microbiome as shown in a study in the United States comparing two pasture-raised broiler flocks. Although the two farms raised the same chicken breed obtained from the same hatchery and fed the same diets, the physical farm environments influenced the structure and composition of the gut microbiome and the presence of foodborne pathogens (e.g. *Campylobacter* and *Listeria*) (Tsiouris et al., 2015; Rothrock and Locatelli, 2019).

Preventive and corrective measures depend on the most probable cause of GED. The identification/exclusion of the most likely cause of GED (e.g. exclusion of intestinal causes; infectious or non-infectious causes) requires some experience and skills of the staff and/or poultry managers/veterinarian. Mixing whole wheat into standard pelleted broiler feed may help to prevent diarrhoea since it has positive effects on the overall digestion and improving gut health (de Jong et al., 2012a). It should always be verified if there have been substantial changes in the feed (composition) when GED are observed, to adjust treatment and prevent the same event to happen in the next flocks. Good quality feed, combined with regular cleaning and disinfecting of feed and water equipment, including the removal of any caked and mouldy residues lodged in the system, should help prevent GED.

Anticoccidial drugs are used to prevent coccidiosis, but resistance to these drugs is common. Alternatively, vaccination can be used to prevent coccidiosis, although this is not commonly applied in broiler chickens due to the relatively high costs for the relative short rearing period of broilers. Alternatives, such as additives in feed or drinking water (phytogenic, probiotics, prebiotics, fatty acids, etc.) can promote gut integrity, support the gut after infection or reduce infection, but are not considered an alternative to anticoccidial drugs or vaccination (Broom, 2021). Water treatment like acidification is a preventive solution to sanitise the water (Haughton et al., 2013).

3.4.2.7. Prolonged hunger

Description of WC, category of bird and husbandry systems

'Prolonged hunger' was identified by the working group experts as a highly relevant welfare consequence for day-old chicks hatched in hatcheries and broiler breeders in all husbandry systems, but different reasons apply for the two animal categories. A general definition of 'prolonged hunger' is provided in Table 5.

Day-old chicks

Feed and water are typically either both absent or both present in the hatchers and during the holding time. Thus, if prolonged hunger occurs, then prolonged thirst is likely to co-occur and vice versa. When a newly hatched chick experiences prolonged hunger and thirst, body weight loss will occur. A post-hatch feed deprivation period of on average 48 h (between 36 and 60 h) or longer results in increased mortality and impaired performance even if the yolk sac may provide some nutrients for up to 72 h post-hatch (de Jong et al., 2017). Effects on organ development and physiological indicators appear to be mainly short term (de Jong et al., 2017). However, there is a high uncertainty of the exact threshold for post-hatch food and water deprivation to result in increased mortality, as studies varied in whether they assessed these effects post-pull or post hatch, in the hatching and housing conditions, and the exact durations of post hatch feed and water deprivation. Moreover, only mortality and performance effects could be analysed in the study of de Jong et al. (2017) as studies including other indicators of prolonged hunger, such as latency to feed or total feed intake, were lacking.

Broiler chicks and broiler breeder chicks hatched in a hatchery without a system providing feed will all experience prolonged hunger to some degree, and some of them will experience prolonged hunger for a duration that has been shown to impose negative effects on welfare (de Jong et al., 2017). However, when placed in the barn, broiler chicks quickly find and learn how to ingest feed which is available *ad libitum*, i.e. prolonged hunger is rarely experienced for more than 72 h, and usually for a shorter period.

Broiler breeders

Since broiler breeders have similar genetics to broilers, who have been selected for fast growth and high feed efficiency, all broiler breeders experience some level of feed restriction (Siegel and Wolford, 2003). This feed restriction is most severe during the rearing period, and more severe for the very fast-growing hybrids than for the more slowly growing hybrids (Puterflam et al., 2006; Arrazola and Torrey, 2021). The intention is to reduce health and welfare issues linked with lameness due to overweight, at ages beyond that when a normal broiler chicken would already have been slaughtered. Non-feed restricted birds also have an altered ovarian function resulting in poor fertility during the egg production phase (Hocking et al., 2002). This conflict and the difficulty in reconciling good health and reproduction without recourse to some form of feed restriction and the birds experiencing prolonged hunger has been called the 'broiler breeder paradox' (Decuypere et al., 2010).

In broiler breeders, prolonged hunger does not lead to a weakened condition, but only a suppression of growth, i.e. impaired growth rate, as normally the metabolic requirements are met despite restrictive feeding. Nevertheless, broiler breeders experience a negative affective state and lack of fulfilment of basic behavioural needs for feeding and foraging (de Jong et al., 2005; Van Krimpen and de Jong, 2014). When there is fierce competition between severely feed restricted birds, some birds may be prevented from gaining the daily feed ration by stronger birds, further increasing the severity of prolonged hunger in some individuals. However, Lindholm et al. (2015) argued that some of these birds may habituate to the situation, reducing the negative welfare imposed. In general, birds exposed to feed restriction, and therefore experiencing prolonged hunger, show elevated levels of stress hormones and reduced density of new neurones in the hippocampal regions of the brain (Robertson et al., 2017) and so reduced learning capacities (Buckley et al., 2011).

The majority of broiler breeders will normally have restricted access to feed from about 7–10 days of age until the end of life. The severity of the feed restriction is high during the rearing period where the restriction level reduces the feed quantity down to 20–25% of what a broiler breeder pullet would eat if having *ad libitum* access to feed (Riber, 2020). During the laying period, the broiler breeder hens allocate much energy to the eggs produced and the feed restriction level is therefore relaxed and for some slower-growing hybrids feed restriction may not even be practiced during the laying period. Nevertheless, the duration of the prolonged hunger in broiler breeders can be considered extensive since it occurs throughout most of the rearing period.

Description, measurement, interpretation and characteristics of ABMs

Related ABMs for 'prolonged hunger' are 'body weight loss' (see Section 3.4.2.21) and 'mortality' (see Section 3.4.2.21) for day-old chicks and 'impaired growth rate', 'polydipsia', 'stereotypic behaviour' (see Section 3.4.2.21) and 'injurious pecking' (see Section 3.4.2.21) for broiler breeders.

Day-old chicks

The ABMs identified for day-old chicks are the iceberg indicators 'body weight loss' and 'mortality'. Increased first-week and total mortality may be related to prolonged hunger post-hatch (de Jong et al., 2017). In addition, a rebound in feeding behaviour and/or feed intake may indicate prolonged hunger (Tolman and Wilson, 1965).

Broiler breeders

Impaired growth rate

Definition	A reduction in growth rate that leads to a deviation of the expected growth trajectory in broiler breeder chickens during rearing.
Measurement	The lower the growth rate compared to the expected growth trajectory, the lower the feed intake. The low feed intake is generally associated with prolonged hunger.
Interpretation	Weighing the birds on individual basis, either manually or automatically (Li et al., 2021c).
Sensitivity and Specificity	The ABM is of high sensitivity as the growth will be reduced, compared to the expected growth trajectory, when breeders are exposed to prolonged hunger. The ABM is of low specificity since when there is no prolonged hunger, 'impaired growth rate' may appear for other reasons (e.g. due to disease).

Polydipsia

Definition	Increased water intake in restrictedly fed broiler breeders experiencing prolonged hunger compared to previous days' water consumption or to what it is expected from birds unrestricted in feed (Mench, 2002).
Measurement	Measurement of water consumption, observations of drinking behaviour or wet litter (Li et al., 2018).
Interpretation	Hungry birds drink to fill the gastrointestinal system as a compensation for feeding; excessive drinking is also a sign of frustration (Savory and Mann, 1997).
Sensitivity and Specificity	It is of low sensitivity because when 'prolonged hunger' is present, birds will not always show 'polydipsia'. The behaviour is only moderately specific since even without 'prolonged hunger', 'polydipsia' can be present (e.g. in sick birds). The specificity will increase if other (pathological) causes can be excluded.

Birds that are feed restricted are more likely to develop spot pecking (Hocking et al., 2001, 2002, 2004; Merlet et al., 2005) (or pecking at empty food troughs (Girard et al., 2017a)), which are considered as stereotypic behaviour. Prolonged hunger favours the development of feather pecking leading to plumage damage in the neck/back (Girard et al., 2017a). It is used to assess the extent of stress in breeder pullets (Morrissey et al., 2014). Feather damage is not specific for the welfare consequence 'prolonged hunger' since it is commonly found in laying hens without any feed restriction. Stress can be elicited by many causes including 'prolonged hunger' as the most serious welfare consequence in this type of animal. The conspicuous way of pecking the feathers of other birds or their own feathers in a stereotypic way was termed 'feather licking' by (Arrazola et al., 2020b). 'Prolonged hunger' also causes aggressive behaviour among hens and roosters as they compete for feed (Hocking and Jones, 2006). Eating eggs can occur in all chickens but may be more pronounced in fed restricted broiler breeders.

Note that broiler breeder chicks are commonly not feed-restricted during the first two weeks, so the ABMs defined for broiler breeders do not apply during this time. However, the parental generation of broiler breeders (i.e. grandparents of broilers) are generally not kept in the respective countries where they will be reared, so broiler breeder chicks might be transported for a longer time including being held at customs overnight.

Hazards and preventive and corrective measures

Day-old chicks

Hazards

The most important hazard is a post-hatch water and feed deprivation of on average 48 h or longer (range 36–60 h) (de Jong et al., 2017). Especially early hatched chicks in combination with a long hatch window are at risk (van de Ven et al., 2011), but more general, if no water and feed is provided post-hatch and chick processing and the holding period (i.e. waiting at the hatchery and/or transportation) take more than 48 h there is a risk of prolonged thirst and prolonged hunger (Willemsen et al., 2010a; de Jong et al., 2017). Also, a disruption in water and food supply, which may happen both at the hatchery (in cases where an early feeding system is applied) or on the farm, is a hazard for prolonged thirst and prolonged hunger.

Preventive measures for the hazards

Prolonged thirst and prolonged hunger can be prevented by providing water and feed or liquid feed immediately post-hatch in the hatchery (Van der Pol et al., 2015; Souza da Silva et al., 2021) and during transport or by applying on-farm hatching where the chicks have access to feed and water immediately post-hatch (van de Ven et al., 2009; Souza da Silva et al., 2021). A shortening of the duration of the hatch window will reduce the risk of prolonged thirst and prolonged hunger in early hatched chicks (Bergoug et al., 2013a). Furthermore, minimising post-hatch handling, holding in the hatchery and transport will reduce the time until access to water and feed on-farm and prevent prolonged thirst and prolonged hunger (Careghi et al., 2005; Willemsen et al., 2010b).

Corrective and mitigative measures

To reduce the period of water and feed deprivation, chicks should be unloaded from the truck and placed in the barn on paper with feed particles directly under the water lines immediately after arrival to the farm.

Broiler breeders

Hazards

The main hazard for the mentioned ABMs is feed restriction applied to currently used hybrids (due to genetic selection). When feed restriction decreases the uniformity in the flock, smaller pullets fall behind and the welfare consequence 'prolonged hunger' is exacerbated for these individuals. Another hazard is the hybrid as the faster the broiler breeder grows, the stricter the feed restriction needs to be.

Preventive measures

In fast-growing hybrids, preventive measures are very limited. To reduce the feeling of prolonged hunger due to severe feed restriction and to ensure that all birds have the opportunity to feed and are not excluded by stronger individuals, several methods of feeding schedules, diet dilutions by adding different types of fibres or appetite suppressants have been used. An overview is provided in specific ToR 3 (see Section 3.7). However, even if some differences in behaviour are observed, which may suggest that qualitative feed restriction may improve bird welfare, when compared to the standard commercial practice, birds still seem to experience a considerable level of hunger when restricted.

Spin feeding might make the feed more accessible to all birds at once and prevent stronger individuals from monopolising the feed (Aviagen, 2018b). For the same purpose, the light might be turned off just before the feed chain starts running and is turned on once the feed is available in the trough throughout the barn.

Another preventive measure is the use of more slowly growing hybrids and hybrids with dwarfed hens leading to a shorter period of a milder form of feed restriction, for example only during rearing. A more successful preventive measure is the use of dual-purpose hens whose breeders do not need to be feed-restricted at all at least during the production period (Müller, 2018).

In conclusion, the broiler breeder paradox meaning that these birds have to be severely restricted for health reasons but at the same time suffer from it, precludes preventive and corrective measures to a large extent. However, within this paradox, a smaller degree of restriction can be beneficial for broiler breeder companies because the practiced level is (besides health reasons) optimised for profit by saving feed costs.

Corrective Measures

In case of (too) low uniformity, size grading and regrouping the chicks is a potential corrective measure. This consists of grouping the birds in similar weight classes to prevent small individuals to fall behind (Dixon, 2020). Another possible corrective measure would be precision feeding (Zuidhof et al., 2017) but this has been shown to cause more aggression in one study (Girard et al., 2017a).

3.4.2.8. Prolonged thirst

Description of WC, category of bird and husbandry systems

'Prolonged thirst' was identified by the working group experts as a highly relevant welfare consequence for day-old chicks hatched in hatchery and broiler breeders kept in floor systems and broiler breeders kept in multi-tier systems. A general definition of 'Prolonged thirst' is given in Table 5.

Day-old chicks

Day-old chicks hatched in a hatchery do typically not have immediate access to water and feed. Especially early hatched chicks are at risk of prolonged thirst and prolonged hunger (see Section 3.4.2.7) (van de Ven et al., 2011) as they need to stay in the hatcher until the remaining chicks hatch, after which the chicks are handled (e.g. collected, sorted, vaccinated, packed in boxes) and transported to the farm. This post-hatch pre-placement period may last 50 h or longer (up till 72 h in case of long-term transport, Council Regulation (EC) No 1/2005[6]) (Willemsen et al., 2010b; Bergoug et al., 2013b). Post-hatch water deprivation (without feed deprivation) of 24 h or longer may lead to dehydration (Xin and Lee, 1997; Joseph and Moran, 2005; Fairchild et al., 2006) and a lower body weight in the first week (Noy and Sklan, 1999), but no effects on long-term performance, mortality and yolk sac absorption have been found (Noy and Sklan, 1999). Post-hatch water deprivation (without feed deprivation) of 24 h or longer may lead to dehydration (Xin and Lee, 1997; Joseph and Moran, 2005; Fairchild et al., 2006) and a lower body weight in the first week (Noy and Sklan, 1999), but no effects on long-term performance, mortality and yolk sac absorption have been found (Noy and Sklan, 1999). A meta-analysis of existing studies concluded that 48 h (range 36–60 h) of post-hatch water (and feed) deprivation compromise the welfare of the chicks (de Jong et al., 2017). However, this paper showed a relatively large uncertainty range for the post-hatch water (and feed) deprivation where day-old chicks experience prolonged thirst, as there was limited literature where experiments were conducted with chickens deprived post-hatch or post-pull, and with different durations of deprivations. Moreover, regarding welfare, mortality was the only indicator that could be included in the meta-analysis and information on other welfare indicators was lacking.

Broiler chicks and broiler breeder chicks hatched in a hatchery without a system providing feed and water or moist feed will all experience prolonged thirst to some degree, and many of them will experience prolonged thirst for a duration that has been shown to impose negative effects on welfare (i.e. > 48 h; de Jong et al., 2017). When placed in the barn, chicks quickly find and learn how to use the drinking nipples where water is provided *ad libitum*. That means that prolonged thirst is of a temporary character in chicks hatched in a hatchery as it is rarely experienced for more than 72 h, and usually for a shorter period. Thus, the prevalence is high, the severity is high, whereas the duration is moderate.

Broiler breeders

In broiler breeders, access to water is often restricted to prevent excessive drinking or manipulation of the water dispensers (Hocking, 1993). The feed restrictions applied to broiler breeders due to the high growth potential can lead them to interact more with the drinkers to consume more water (polydipsia) as well as for other reasons than water consumption (Hocking, 1993) and both leading to poorer litter quality. Birds with polydipsia increase their water intake which leads to wetter droppings which in turn lead to wetter litter (Savory and Mann, 1997) and consequently to the ABMs hock burn and FPD (Li et al., 2018). To avoid this, the practice is to limit access to water, e.g. by reducing the flow rate or by limiting access to the water to specific times of the day. Excessive manipulation of water dispensers is a form of spot pecking, i.e. a type of stereotypic behaviour.

Water restriction in broiler breeder housing is widely used in Europe, but there is scarce data on the exact prevalence at which this measure is applied in the EU. If water is restricted, the restriction period may last from about 7–10 days of age until the end of life. Thus, whereas the duration of water restriction can be long, the severity may be considered less significant, as water is provided during part of the day, ensuring at least the minimum required water consumption for sustaining life, growth and production.

Description, measurement, interpretation and characteristics of ABMs

Day-old chicks

For day-old chicks, related ABMs for 'prolonged thirst' are 'mortality' (see Section 3.4.2.21) and 'body weight loss' (see Section 3.4.2.21).

'Prolonged thirst' may also result in 'lethargy' (see Section 3.4.2.21) and prostration (being unable to stand (Borges et al., 2004)).

Broiler breeders

For the broiler breeders, related ABMs for 'prolonged thirst' are 'stereotypic behaviour' (see Section 3.4.2.21), the 'pinch test' and the 'voluntary water test consumption'.

Pinch test[13]

Definition	The 'pinch test', also termed the skin tent test, is a test for dehydration (not for thirst per se), where the delay in return of a fold of pinched skin to its normal position indicates the level of dehydration.
Measurement	The time interval between releasing the skin and the re-establishment of the previous skin condition (Vanderhasselt et al., 2013).
Interpretation	The slower the return of the pinched skin, the more dehydrated the individuals (Sprenger et al., 2009; Vanderhasselt et al., 2014) and the more likely the prolonged thirst.
Sensitivity and Specificity	It is not yet known whether the ABM is valid for thirst in breeder. The ABM has low sensitivity, as 'prolonged thirst' not always leads to increased time in the pinch test (Vanderhasselt et al., 2013). Specificity is presumably high because in the absence of dehydration due to 'prolonged thirst' the test will be negative.

Voluntary water test consumption

Definition	A test of voluntary water consumption from an unfamiliar open drinker (Vanderhasselt et al., 2014). The test is not affected by location within the house, suggesting that it could be a rather robust measure of thirst.
Measurement	Birds are presented an unfamiliar open drinker and their water consumption during a given time period is measured (Vanderhasselt et al., 2014).
Interpretation	Thirsty chickens are more likely to overcome the novelty of an unfamiliar drinker and start drinking. The more thirsty the chickens are, the higher their water consumption (Vanderhasselt et al., 2014).
Sensitivity and Specificity	The ABM has high sensitivity. Thirst will lead to a high motivation to consume water to still thirst. The ABM has high specificity because if animals are not thirsty, the water intake from this test will be low or nil. In addition, packed blood cell volume and body water content have been used as an indicator of 'prolonged thirst', but this requires blood sampling and/or killing of chickens and is therefore not feasible in the field (Xin and Lee, 1997). Increased cloacal temperature (more than 40.5°C) of chickens may indicate a too high environmental temperature and a risk of dehydration (Maman et al., 2019) and therefore 'prolonged thirst'. Immediate and prolonged drinking behaviour as soon as water is available may also indicate prolonged thirst/dehydration, as well as level of water consumption (Vanderhasselt et al., 2014). Drinking behaviour can be measured by manual scoring of chickens showing drinking behaviour or by automated scoring based on video imaging analysis of behaviour (Li et al., 2020). Furthermore, as a proxy of problems regarding water consumption, the water usage in the barn as indicated in the barn computer should be consulted, regularly. Water consumption is an easy to assess welfare indicator (Manning et al., 2007a). A change in the water usage is an early warning sign for leakages or problems with the birds as water consumption is often correlated with feeding.

Hazards and preventive and corrective measures

Day-old chicks

Specific hazards and preventive and corrective measures for 'prolonged thirst' in day-old chicks are listed here. Others are linked to those for 'prolonged hunger' and can be found in Section 3.4.2.7 on day-old chicks.

Hazards

In addition to delayed access to water (see Section 3.4.2.7 on day-old chicks), too high environmental temperatures and/or inadequate ventilation (in chick boxes) during the post-hatch holding period are hazards of 'prolonged thirst', as they may result in dehydration (Xin and Harmon, 1996; Maman et al., 2019), and thus result in an escalation of the chick's sensation of prolonged thirst.

[13] The pinch test has been used in only one study as a dehydration indicator for broiler chickens at slaughter. The test is likely only useful if birds are experiencing severe prolonged thirst, resulting in significant dehydration. It has not been examined how the pinch test and the voluntary consumption test correlate.

Preventive measures for the hazards

In addition to providing access to water (see Section 3.4.2.7 on day-old chicks), ensuring an appropriate effective temperature (30–35°C) during holding in the chick boxes will reduce the risk of overheating that may lead to dehydration, which is particularly important in chicks experiencing prolonged thirst (Maman et al., 2019). This can be done by reducing the number of chicks in the boxes, increasing ventilation, reducing environmental temperature and providing water via gel while in the boxes. More information regarding the transport period can be found in the Scientific Opinion on the welfare of domestic birds and rabbits transported in containers (EFSA AHAW Panel, 2022a).

Corrective and mitigative measures

See Section 3.4.2.7 on day-old chicks.

Broiler breeders

Hazards

Hazards are related to the availability of water, the type of food eaten (some substances have diuretic effects), the health of the birds (diarrhoea can affect how quickly a bird becomes dehydrated and feels thirsty), and the effective temperature. 'Prolonged thirst' can also be caused by high effective temperature (e.g. in tropical climates, during heat waves) and by unplanned disruptions in the water supply. If the drinkers are of a different type or in a different location in the laying house compared to the rearing house, or moved during rearing, some birds may be slow to locate the drinkers and so experience prolonged thirst during this initial period or even die (Gebhardt-Henrich, personal communication, 7 October 2021). For some individuals in the flock, 'prolonged thirst' may also be affected by the location of the drinkers and the social dynamics within the group, as some broiler breeders may be prevented from accessing the drinkers even when water is available, e.g. lame or low ranked individuals. If the water is placed on raised slats, broiler breeders reared in floor systems without perches may experience difficulties learning where to find the water. This seems to be particularly evident for males (Agnethe Spangberg, DanHatch A/S, DK, personal communication, 26 October 2015).

Preventive measures for the hazards

Slats underneath the drinkers may help to prevent wet litter in case of polydipsia and would allow to restrict water less or not at all. Appropriate control of the temperature within the house, good backup systems in the case of unexpected events disrupting water supply and rearing the birds in a similar system to that they will be housed in as adults can all reduce the risk of birds experiencing prolonged thirst. Alternatively, water may be provided *ad libitum* for any hybrid of broiler breeders, if water lines are placed above slatted floors to allow draining of water spillage and drinking nipples specially designed for broiler breeders are used. These drinking nipples allow small amounts of water at a time, and thus reduces the risk of overconsumption and spillage. This likely needs to be combined with high ventilation efficiency and good quality litter to keep the litter dry in case of moist faecal droppings.

Corrective and mitigative measures

Access to water should be given *ad libitum*.

3.4.2.9. Heat stress

Description of WC, category of bird and husbandry systems

'Heat stress' was identified by the working group experts as a highly relevant welfare consequence for chickens for meat production kept in mobile housing system. A general definition of 'heat stress' is given in Table 5.

Heat stress is mainly experienced by birds that have access to outdoor areas and those in mobile housing. More attention is paid to heat stress than cold stress during rearing of broiler chickens because it is more prevalent. Although heat stress can be present in both fast- and slower-growing broiler chickens under high ambient temperatures, fast-growing broiler chickens produce more metabolic heat as compared to slower-growing hybrids and can therefore be more susceptible to heat stress (Deeb and Cahaner, 2002; de Jong et al., 2012a).

As illustrated in Figure 14 and described in (EFSA AHAW Panel, 2022a), broilers subjected to heat stress show a range of behavioural, physiological and immunological responses to try to cope with the high ambient temperatures and to keep their core body temperature within the range of 40–41°C (ranges C and D in Figure 14) (Kumar et al., 2021). For a full description of the heat stress mechanism, see EFSA AHAW Panel (2022a).

When the temperature increases, broilers will change their behaviour to try to cope with the heat stress. They will reduce eating and increase drinking behaviour (Chowdhury et al., 2012; Kumar et al., 2021), reduce locomotor activity by increasing sitting and lying behaviour (Branco et al., 2020; Branco et al., 2021; Del Valle et al., 2021) and spread their wings from the body (Lara and Rostagno, 2013). They will also stay closer to the drinkers and/or to the air inlets (Akter et al., 2022). With high ambient temperatures broilers start panting (deep breathing with open beak). This is very important at high temperatures as poultry lack sweat glands; therefore, most of the heat loss occurs through the respiratory route (Bell et al., 2001) through evaporative cooling by the vaporisation of moisture from the damp lining of the respiratory tract (lungs and air sacs) (Gupta, 2011). If broilers fail to cope with heat stress, their body temperature will rise and at some point (above D in Figure 14), they will become lethargic and eventually die. The point of fatality varies between individuals and species but is usually about 4°C different from normal Core Body Temperature (DEFRA, 2005).

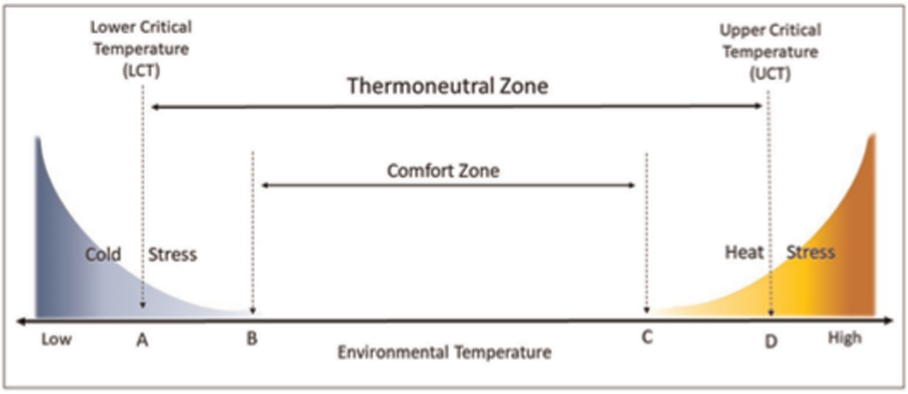


Figure 14: Schematic representation of the thermoneutral zone and the comfort zone as a function of the environmental temperature, considered especially relevant for the assessment of animal welfare of broilers on farm (EFSA AHAW Panel, 2022a)

The susceptibility of poultry to heat stress varies according to the magnitude of the thermal challenge (which is a combination of temperature and humidity) (Lara and Rostagno, 2013), its duration, characteristic of the birds (the hybrid, physiological status, age, maturity, body weight/ metabolic body size and the degree of acclimatisation), as well as access of birds to resources (e.g. food, water and shelter and stocking density). Genetic selection programs aimed specifically at production traits resulted in increased sensitivity of broilers to high ambient temperatures owing to the strong correlation between production levels and heat production in broilers (Deeb and Cahaner, 2002; Sandercock et al., 2006; Renaudeau et al., 2012), but this might be less relevant for slower-growing animals with outdoor access. The older the chickens, the higher the metabolic rate and the lower the ambient temperature at which they will perceive heat stress (Meltzer, 1987). Further, high stocking densities increase the risk for heat stress (Najafi et al., 2015) because more heat is produced by the other animals and heat cannot be dissipated as efficiently as with lower stocking densities. Management guides of the breeding companies provide the required environmental temperatures for the different ages and under different conditions (for different combinations of humidity and stocking densities), but not the temperature above which heat stress starts.

Mobile houses might be exposed to full sunshine and adjust the indoor temperature at least to the temperature outdoor, plus solar radiation. In most of the fully mobile houses, no mechanical ventilation systems are built-in which might expose the chicken to thermal heat stress. Passive ventilation which is always present helps to decrease the temperature inside the barn but might be insufficient in case of an acute heat wave. The risk of heat stress might be increased at higher stocking densities, as broilers have more problems to dissipate heat at high stocking densities (de Jong et al., 2012a; Najafi et al., 2015), although this is not often the case in slower-growing chickens in mobile housing. Weather conditions (e.g. storm) or outdoor areas that cause the birds not to range outside, worsen the situation.

'Heat stress' has been selected as highly relevant in this opinion for birds reared in mobile housing, but heat stress may happen in any other system because of heat waves that are increasingly frequent in the context of global warming. Especially fast-growing chickens, usually reared fully indoor, have high metabolism, generating high heat production, which is not easy to dissipate when they are on the litter. They are, thus, very sensitive to heat stress in case ventilation and cooling systems are not able to regulate temperature due to heat waves.

Chickens for meat production kept in mobile systems with free range

Heat stress in mobile systems might be of short duration, e.g. couple of days per season, but can result in an enormous severity with high mortality in the flock. Typically, losses occur when birds are kept inside during the first phase of the rearing period or due to technical problems preventing the birds to leave the hutch. This applies primarily to mobile systems, as these generally have no air conditioning and rarely mechanical ventilation and are particularly exposed to solar radiation due to low insulation and low internal volume. The frequency of such episodes is difficult to estimate, as it usually refers to a few hot days per year. However, the risk of high mortality should not be underestimated.

Description, measurement, interpretation and characteristics of ABMs

Related ABMs for 'heat stress' are 'panting', 'wings are held away from the body', and 'lethargy' (Section 3.4.2.21).

Panting

'Panting' is an ABM for chicks and chickens. 'Panting' is described as ABM in the Welfare Quality® Assessment Protocol for Poultry. The chickens show breathing via the open beak, to promote heat loss via the respiratory route.

Definition	Breathing with short, quick breaths with an open beak (Welfare Quality®, 2009).
Measurement	Observation of the proportion of chickens showing this behaviour in a representative sample of chickens.
Interpretation	When a chicken is panting, it actively increases heat dissipation via the respiratory route. The more panting is seen in the flock the more heat stress is present.
Sensitivity and Specificity	The ABM has high sensitivity, as chickens will pant when experiencing heat stress. The ABM has high specificity, as panting only occurs during heat stress.

Wings held away from the body

Definition	The bird is holding both wings away from the body to radiate heat from areas of the body with little feathering but good blood circulation in order to decrease its core temperature. This body posture also termed wing-drooping, is used as a thermoregulatory mechanism to dissipate excess heat in chickens (Santos et al., 2019).
Measurement	Observation of the proportion of chickens showing this behaviour in a representative sample of chickens.
Interpretation	When a chicken is holding the wings away from the body, the body surface area exposed to the air flow increases, whereby convective heat dissipation increases. The more birds with wings holding away from the body, the more birds are showing heat stress.
Sensitivity and Specificity	The ABM has moderate sensitivity, as chickens experiencing heat stress will not always show the wings held away from the body. The ABM has high specificity, the ABM will not be seen when heat stress is not present.

Hazards and preventive and corrective measures

Hazards

High effective temperature is the hazard for heat stress, which is the combination of the dry bulb temperature and relative humidity. With high relative humidity, chickens have more difficulties dissipating heat to the environment and thus will suffer more from heat stress as compared to low relative humidity with the same environmental temperature. Mobile houses with free range that are poorly protected or insulated from sunlight and lack ventilation are hazards for heat stress. High stocking density inside the mobile house constitutes a hazard for heat stress. Fast-growing hybrids have more problems dissipating heat than slower growing hybrids as they have a higher metabolic rate. Lack of shelter in the outdoor range can be also a hazard for heat stress.

Preventive measures

Broiler chickens are better able to cope with heat stress with a decreased stocking density, proper ventilation, low relative humidity, provision of cold water and adapted nutritional strategies such as addition of vitamins and feeding outside hot hours (Kumar et al., 2021). As the litter generates heat, providing elevated wire platforms or perches where chickens can move away from the litter may reduce heat stress (Gebhardt-Henrich et al., 2017b).

The choice of location for the mobile houses based on solar radiation is important: Mobile houses should be placed in the shade during summer. The orientation of the side of the entrance (preferably towards the west) and the exit will play an important role to have a lower temperature in the house. Insulation of the roof in particular plays an important role in temperature regulation. Ventilation should be provided in a way that heat does not accumulate in the mobile house. This is most easily provided by active ventilation, but passive ventilation on the four sides of the house and especially the ridge or other high positions may also ensure good ventilation in mobile housing that are of small size. Shelter in the outdoor range (preferably natural shelter such as trees) is also essential to prevent heat stress in systems with outdoor range (Santos et al., 2014). Reducing stocking density through thinning and providing elevated structures will help to prevent heat stress.

Corrective and mitigative measures

Provide artificial shelter in the outdoor range if not present yet, and spraying water on the roof if no other alternative is available.

3.4.2.10. Handling stress

Description of WC, category of bird and husbandry systems

'Handling stress' was identified as a highly relevant welfare consequence for day-old chicks hatched in hatchery and broiler breeders kept in individual cages. A general definition of 'Handling stress' is given in Table 5.

After removal of the chicks from the hatcher, newly hatched chicks are subjected to procedures such as selection, vaccination, counting and crating, usually done by automated systems and involving rollers and high-speed conveyor belts (Knowles et al., 2004). The speed of the conveyer belt affects the orientation and posture of the chick. During this process, chicks may also experience drops between different levels in the system and falls to the floor, either from the belt or due to accidental drops during the handling. When this happens there will be a righting time, during which the chicks regain their normal sitting or standing posture. Chicks that fall on the floor may get injured and experience pain and fear. In some cases, it may even result in dislocation and broken bones. If they stay on the floor, they may experience additional welfare consequences, such as 'cold stress', and risk being accidently stepped on by personnel or run over by racks/other equipment, even causing fatality. The description of the impact of handling stress on chicks' welfare during 'pre-crating' stages is described in (EFSA AHAW Panel, 2022a). No impact of hatchery processes on welfare or production of broilers were reported but increasing drop heights and conveyor belt acceleration led to disorientation and discomfort in the chicks (Giersberg et al., 2020). In addition, occurrence of chicks falling on the floor indicate rough hatchery procedures, including handling of the chicks, too high conveyor belt speed and/or flaws in the system. For these reasons, the prevalence of handling stress (due to manual or automated manipulation) is considered high in day-old chicks.

Breeding birds kept in individual cages, and in many cases also birds kept in collective cages, can be expected to be handled in connection with collection of sperm and AI and this is likely to involve some aspect of fear for the bird. These procedures usually take place weekly (van Krey and Siegel, 1976), although more recent information suggests that AI takes place more often, i.e. twice per week or sometimes every 5 days (EFFAB, personal communication, 8 September 2021). AI involves catching the hen, holding it by the legs and inseminating it which is known to be stressful (de Jong and Guemene, 2011). Birds may show resistance to handling and escape attempts. Two people are involved: one person presses the left side of the abdomen so that the hen everts her vaginal orifice through the cloaca; at the same time, the semen is deposited by the second person to a depth of 2–4 cm into the vaginal orifice (Mohan et al., 2018). For the males, harvesting sperm also involves repeated handling, restraining and putting pressure on the abdomen, which induces stress.

The duration of the handling is usually relatively short both for the day-old chicks and the breeding birds, although this may vary between hatcheries depending on the length of the conveyer belts and according to working practices between farms with breeding birds. The severity, however, is high since it almost always involves lifting and restraint. In the hatchery, the design of the automated systems will affect level of handling stress. For breeding birds in individual cages, the skill of the handler and the extent to which breeding birds are habituated to the process will be important. The prevalence varies according to the category of bird. All chicks will be handled at the hatchery, whereas for breeding birds, the handling may be weekly during the laying period or only during certain time periods, in association with data collection.

Description, measurement, interpretation and characteristics of ABMs

Day-old chicks

ABMs for 'handling stress' in day-old chicks are 'chick righting time', 'orientation and posture on the conveyor belts', 'chicks falling on the floor', 'mortality' (see Section 3.4.2.21) and 'fear response' (see Section 3.4.2.21).

Chick righting time

Definition	The time taken for a chick to regain normal sitting or standing posture, when placed on its back (Boerjan, 2002).
Measurement	The amount of time it takes a chick to right itself when placed on its back on an open and stable surface (Knowles et al., 2004).
Interpretation	The longer the righting time, the more severe handling stress experienced by the chick.
Sensitivity and Specificity	The ABM has low sensitivity as minimal effect is found of hatchery procedures on chick righting time (Knowles et al., 2004; Giersberg et al., 2020). The ABM has low specificity, as righting time can also be affected by other factors such as location in the hatchery (Knowles et al., 2004).

Orientation and posture on the conveyor belts

Definition	Orientation of the head (forward, backward, sideways) and posture (sit, stand, lie) and retaining this position/posture on the conveyor belts (Giersberg et al., 2020).
Measurement	Measuring the posture (stand, sit, lie) and orientation (facing forward, backwards, sideways) of each chick before the drop and after the drop on another belt per time unit, and scoring the proportion of chicks with posture or orientation change (Giersberg et al., 2020).
Interpretation	The more changes in orientation and posture of the chicks following belt drops, the higher the handling stress (Giersberg et al., 2020).
Sensitivity and Specificity	The ABM has high sensitivity as with an increased drop height and belt speed (handling) changes in orientation and posture are more frequent. The ABM has low specificity as other things than the hatchery procedures, such as alertness, exploration or sleepiness, may cause the chicks to change their orientation and posture.

Chicks falling on the floor

Definition	Chicks falling from different heights on the floor during the hatchery procedures.
Measurement	The number of chicks falling on the floor per time unit is counted in 'at risk' areas (manual or mechanical handling of the chicks).
Interpretation	The higher the occurrence of chicks falling on the floor, the more handling stress.
Sensitivity and Specificity	The ABM has low sensitivity as chicks may suffer from handling stress without falling on the floor. The ABM has high specificity, as in the absence of handling stress, there will be no chicks falling on the floor.

In addition, the number of chicks with trauma indicate rough hatchery procedures, including handling of the chicks.

Broiler breeders

ABMs for 'handling stress' in broiler breeders are 'escape attempts' and 'resistance to handling'.

Escape attempts

Definition	Attempts to move, run or fly away from a fear-provoking stimulus (Graml et al., 2008).
Measurement	Observation of the proportion of breeders showing this behaviour in a representative sample of chickens.
Interpretation	Escape attempts during handling indicate that handling stress is experienced by the chickens.
Sensitivity and Specificity	The ABM has high sensitivity, as chickens will often express escape behaviour when experiencing handling stress. The ABM has moderate specificity, as escape behaviour may occur due to other fear-provoking stimuli than handling, such as sudden loud noises.

Resistance to handling

Definition	Moving, running or flying away or attempts to do so (i.e. struggling), often accompanied by vocalisations at the time of handling.
Measurement	Each occurrence of moving, running, flying to escape being handled or during handling performed by the breeders is counted.
Interpretation	The more behavioural indicators of resistance, the more the bird is stressed by handling and restraint.
Sensitivity and Specificity	This ABM is of low sensitivity because if a bird does not struggle it might still be very fearful, e.g. in the case of tonic immobility. 'Resistance to handling' has high specificity since it is absent when there is no handling stress.

Hazards and preventive and corrective measures

Day-old chicks

A change in velocity (e.g. falling on another belt with a different speed) greater than 0.4 m/sec (Knowles et al., 2004) and drop heights above 280 mm when switching from one belt to another or when dropping into a crate (Giersberg et al., 2021) have been identified as risk factors for the welfare of chicks. Likewise, acceleration, steep gradients and speed of belts (Knowles et al., 2004; Giersberg et al., 2021) have been identified as risk factors for chick welfare, where speeds of 27 m/min or above compromise chick welfare (Giersberg et al., 2021). In addition, falling on the floor or badly designed system components (where chicks become caught, trapped, smothered or crushed) increase the risk of trauma or mortality (Knowles et al., 2004).

Handling stress can be prevented by slowing down the speed of the belts, removing steep gradients of the belts and avoiding a change in velocity between belts. Furthermore, avoiding rough handling of the chicks and ensuring that the belt is designed such that chicks are protected from falling off will prevent chicks from dropping to the floor. Traumas can also be prevented by ensuring proper design and maintenance of the systems so that chicks will not be trapped or caught in part of the system. Constant monitoring of the system is advised (Knowles et al., 2004). Awareness of hatchery workers on potential hazards and welfare consequences as well as training of the workers on how to handle the chicks will prevent handling stress. With on-farm hatching, chicks are not subjected to most of the above-mentioned handling processes (van de Ven et al., 2009; de Jong and Gunnink, 2019; de Jong et al., 2020; Souza da Silva et al., 2021; Jessen et al., 2021a).

If signs of handling stress are shown, corrective measures would be to reduce the speed of the belt and of the manual handling. If a chick has fallen off the belt or accidentally been dropped to the floor, care should be taken to lift it up using both hands to support the body to limit further handling stress imposed to the chick.

Broiler breeders

Handling per se is leading to fear and stress whereas rough handling can lead to pain. When farm workers are under time-pressure handling is usually rougher and more detrimental to the animals. Long working hours for staff and fatigue contribute to the stress of the animals due to rough handling (Craig and Craig, 1985; Cockrem et al., 2010; Gerpe et al., 2021).

Since breeding birds in individual cages are mainly housed for detailed data collection, the main handling will be in association with insemination. Keeping males and females together for natural mating would eliminate the need for AI. Although, for some particular crosses, e.g. a dwarf male with a normal-sized hen, then insemination is necessary even if the birds are kept together (EFFAB, personal communication, 8 September 2021).

Alerting workers handling the animals to welfare issues and continuous training of those handling birds on a regular basis will help. Inspections of the process should be performed, preferentially by independent organisations. Any potential injuries to the birds, e.g. dislocation or broken bones, can be mitigated by training staff, not only in the handling procedure but also in the importance of a good human-animal relationship. While repeating a situation is generally acknowledged to result in decreased reaction times (Tulving, 1990) and so presumably reduced fear, no such improvements are seen if the repeated stimulus is experienced as too aversive (Marchewka and Nowicka, 2007). Thus, it is possible that birds may become habituated to the procedure if handled carefully, which will reduce the fear and stress associated with the procedure, but this cannot be assumed. The panel is not aware of research in this area with broiler breeders.

3.4.2.11. Isolation stress

Description of WC, category of bird and husbandry systems

'Isolation stress' was identified by the working group experts as a highly relevant welfare consequence for Broiler breeders kept in individual cages. A general definition of 'isolation stress' is provided in Table 5.

Chickens are social, gregarious birds that naturally live in groups. When kept in single cages they cannot socialise normally even if they hear and see other conspecifics. Isolation stress can be of different duration depending on the company, the hybrid, and the sex. The primary reasons for keeping these birds in individual cages are mating control and the collection of individual data. The duration can be just 2 weeks for the collection of individual feed conversion rate, e.g. or during the full production cycle (i.e. 20–40 weeks) for mating control. About 1% of all breeders in individual cages are housed in isolation for just a couple days up to 2 weeks (questionnaire to EFFAB, see Appendix A). Therefore, 99% of breeders experience isolation stress for more than 2 weeks. It has been suggested that the severity of isolation stress is higher for females than males and that multiple periods of 2-week long isolation events dampen the stress response over time (Weldon et al., 2016). The reason for sex-dependent severity of isolation stress is the natural dispersal pattern in males. Under natural conditions, males leave the group and are living alone before joining a new group. In another study, indicators of stress did not differ for laying hens in single and collective cages (Keßler et al., 2021). The prevalence of isolation stress in singly housed birds is 100% with males possibly experiencing a lower severity than single housed females. Over the world about 360,000 breeders are housed in single cages, incl. broiler breeders, layer breeders, ducks, and guinea fowl (numbers from EFFAB, personal communication, 8 September 2021). Isolation stress like other stressors can lead to stereotypic behaviours.

Description, measurement, interpretation and characteristics of ABMs

Related ABMs for 'isolation stress' are 'stereotypic behaviour' and 'fear response' (Section 3.4.2.21).

It is possible to see directly whether the bird is housed singly rather than in a group, but it is of importance the extent to which the bird experiences it as stressful. Possible ABMs include distress vocalisations and increased fearfulness. Distress or alarm calls can be recognised by trained person hearing the sound, but there is commercially available equipment and software to monitor poultry vocalisation (Ginovart-Panisello et al., 2020) and identify alarm calls. Fearfulness can be assessed, for example using standard novel object tests (e.g. (Rozempolska-Rucinska et al., 2018)) and escape attempts can be observed and recorded. If the bird is frustrated by the social isolation, an increase in displacement preening can be expected (Zimmerman et al., 2003). When a bird displays displacement preening, the preening movements are shorter and stereotypic and directed to easy-to-reach areas such as the breast (Wood-Gush and Vestergaard, 1989). This can directly be observed, or alternatively plumage damage, e.g. on the breast would be an indicator. Plumage damage in singly housed birds would either be due to displacement preening or physical damage by the equipment of the cage. Isolation stress among other stress factors can lead to further stereotypic behaviour patterns.

Hazards and preventive and corrective measures

The degree of social isolation will affect the magnitude of the welfare consequence for the bird. For example, a bird may be alone in a cage, but within sight and sound of other birds in neighbouring cages. In addition, the duration of the social isolation is important. The age and previous experience of the bird of being socially isolated previously can also play a role (Ericsson et al., 2016); therefore, it might be possible to habituate birds to single housing to some extent (Heiblum et al., 1998).

Housing birds in group is the first preventive measure to avoid isolation stress. If, for selection reasons, individual parameters like feed efficiency, egg parameters, etc., are needed, precision livestock farming methods can allow the measurement of individual birds even when they are kept in groups (see review by Rowe et al. (2019)).

If it is necessary to isolate a bird physically, the duration of time the bird is isolated should be as short as possible. Being able to see and hear other birds may mitigate the level of isolation stress experienced. Environmental enrichment is commonly used to reduce stress and so the development of stereotypic and other abnormal behaviour. Although the panel is not aware of work on enrichment in cages for broiler breeders, the presentation of a pecking device in caged layers did reduce feather pecking (McAdie et al., 2005). However, it is not clear how beneficial such an enrichment device would be in single-housed birds to reduce other forms of abnormal behaviour.

3.4.2.12. Locomotory disorders

Description of WC, category of bird and husbandry systems

'Locomotory disorders (including lameness)' was identified by the working group experts as a highly relevant welfare consequence for chickens for meat production kept in floor systems and for chickens for meat production kept on floor systems with covered veranda. A general definition of 'locomotory disorders' is presented in Table 5.

Lame broilers can experience not only pain but will also suffer from thirst and hunger when they are unable to reach supply lines (Weeks et al., 2000). The connection between locomotion and the hybrid of the animals is undisputed. Generally, slower growing broiler hybrids (hybrids with a growth rate of less than 50 g/day (Dixon, 2020; Dawson et al., 2021)) are less susceptible to develop locomotor problems as compared to fast growing hybrids (Dixon, 2020; Rayner et al., 2020). The mobility of broilers has a large impact on welfare. Broilers need to be mobile for the expression of different behavioural traits such as exploration, foraging and might choose between different locations for comfort behaviour. Moreover, some leg disorders are painful (Hothersall et al., 2016). Therefore, the broiler's ability for locomotion should be maintained throughout the complete rearing period. Currently, in fast-growing chickens, the prevalence of locomotory problems, especially towards the end of the rearing period, can be high. The severity can be high, leading to acute pain and immobility, and the duration can be from few days up to the majority of rearing period.

Factors that increase the risk for locomotory disorders are: genotype, high growth rate, body conformation, nutrition (Bradshaw et al., 2002), bad litter quality (Granquist et al., 2019), high stocking density, low activity levels and infectious diseases (Bradshaw et al., 2002). Bad litter management and/or high stocking densities can lead to wet or caked litter that secondary leads to FPD and hock burn (Baxter et al., 2018a), which is painful and impairs locomotory function of the broilers. Infectious disorders include femoral head necrosis, arthritis and tenosynovitis (Bradshaw et al., 2002). Leg deformations include tibial dyschondroplasia, rotated tibia and valgus-varus deformity (Bradshaw et al., 2002; Granquist et al., 2019; Guo et al., 2019; Tahamtani et al., 2021).

The most common welfare concerns regarding broilers are health-related impacts on locomotion behaviour. These locomotory disorders will affect welfare and performance traits (Granquist et al., 2019). Lameness might have several causes ranging from FPD to severe bone deformations and injuries. Factors such as rapid early weight gain are of primary importance (Tahamtani et al., 2021). Indicators of locomotory disorders have been identified and assessment protocols, including the gait score, have been validated.

Factors favouring locomotory disorders might be different to indoor only floor housing systems and might also have different effects. Lame birds will use the veranda less, and once outside, might have problems to get back indoors again as there is usually a small height difference between the indoor floor (higher) and the outdoor area (lower floor in veranda). Some factors such as the genetic predisposition for dermatitis, other injuries causing impaired locomotion or nutrition might not be altered by the addition of a covered veranda. But factors such as stocking density, litter quality as well as air quality and light might be differently pronounced in a veranda system. Stocking density is usually lower during daytime, but higher at night-time, as the veranda can be included proportionally in the stocking density calculations in some countries. This means that during daytime more space is available per bird inside as well as outside when already some birds use the outdoor area. In turn, less space is available during night-time as stocking density is calculated taking a given proportion of the veranda into account (usually 20%). Still, during the activity phase of the broiler, the space allowance per bird is higher.

In floor systems with covered veranda, litter quality might be more difficult to handle, since large popholes facilitate more air and humidity flowing indoors with bad weather. This humidity might condense on the ground floor and litter, especially during winter times when the surface is cooler than the air temperature. The bird's access to good air quality and natural light, as well as an outdoor climate stimulus will be welfare-supporting (de Jong and Gunnink, 2019).

Description, measurement, interpretation and characteristics of ABMs

ABMs for 'locomotory disorder' include 'flock activity', 'leg deformation' and 'walking impairment' (Section 3.4.2.21).

Flock activity

Definition	The level of activity within a flock, evaluated by the aggregation of the individual's movement and the prevalence of (ab)normal activity patterns. Activity includes predominantly locomotion which can be impaired, e.g. by lameness. Activity might also reflect other movements, e.g. disturbance of one bird causing another bird to stand up and lay down again (often after a short walking distance). The general activity might, therefore, be led by the mean activity of the flock as well as the level of variation in the flock's activity influenced by the individual.
Measurement	Activity describes the proportion and extent of movements of chickens in a given flock. Different quantitative approaches have been applied which, at present, are mostly based on visual data analysis. Therefore, video recordings have to be made and analysed by an observer or digitally. Optical flow techniques have been used to analyse broiler flock activity (Dawkins et al., 2013). In general, automatic assessment should be favoured and supported (precision poultry farming). 'Active' is also a term to be assessed in the Qualitative Behaviour Assessment.
Interpretation	Activity indicates mobile broilers which are consent to be healthy and in a good welfare status. Inactivity might be caused by pain or diseases and will result in additional reduction of welfare when the chicken experiences pain and might not be able to cover its needs including reaching feed and water lines.
Sensitivity and Specificity	The sensitivity of the ABM is high as locomotory disorders impair the chickens to be active in terms of movement. The specificity of the ABM is moderate since other factors such as high stocking densities might result in a reduced activity.

Leg deformation

Definition	Abnormality of the growth cartilage that results in deformed bones and, at least in severe cases, causes walking impairment (Pines et al., 2005). Tibial dyschondroplasia, rotated tibia and valgus-varus deformity are classified as leg deformation.
Measurement	Birds can be scored by visual examination for pathologies. Scores are based on the angulation of the tibia-metatarsus according to Tahamtani et al. (2018a) and Guo et al. (2019). Special focus is set on the deviation in the vertical axis of the legs, scored on live birds. Severe deviations will be reflected in the gait score. It includes valgus-varus angulation (lateral or medial angulation of the shaft of the distal tibio-tarsal bone) resulting in deviation of the lower part of the leg and frequently with bending of the proximal shaft of the tarsometatarsus (Julian, 1984; Guo et al., 2019; Jiang et al., 2019). The presence of leg deformation can lead to impaired welfare (Guo et al., 2019). The presence of leg deformation can lead to impaired welfare.
Interpretation	The higher the proportion of leg deformation in the flock the more broiler chickens experience locomotory disorders.
Sensitivity and Specificity	The sensitivity is low as when locomotory disorder is present it is not always caused by leg deformation. The specificity is high since in case of no locomotory disorder birds will not suffer from leg deformation.

Hazards and preventive and corrective measures

Broilers on floor systems (indoor)

Factors that trigger locomotory disorders in broilers might predominantly be rapid early growth rate in terms of high daily weight gains, FPD or wooden breasts (Kierończyk et al., 2017) caused by poor litter quality predominantly driven by a high humidity (Granquist et al., 2019), as well as other attributes of a suboptimal physical (including visual) environment (Tullo et al., 2017), including high stocking densities. There will also be an interaction with high stocking densities and barren environments which do not support healthy movements of the herd (Vasdal et al., 2019b), as well as feed and nutritional regime and genotype resulting in too heavy birds. Morphological studies revealed an impact of environmental structuring leading to changes in muscle and bone formation during development which have to be considered for hazards as well as corrective measures (Pedersen et al., 2020).

Preventive measures include controlled weight gain (by selecting and using slower-growing genotypes), good litter quality (Chuppava et al., 2018; Toppel et al., 2019), as well as environmental enrichment will counteract the emergence of lameness. Additional supporting measures are highly debated and in focus of research such as elevated perforated floors, lower pH-values of the bedding material or diet composition (Swiatkiewicz et al., 2017). Readjustments of feeding management and weight gain might be difficult to implement within a given flock. Additional bedding material might prevent FPD, but further research is needed. Preventive measures include controlled weight gain (by selecting and using slower-growing genotypes), good litter quality (Chuppava et al., 2018; Toppel et al., 2019), as well as environmental enrichment will counteract the emergence of lameness. Therefore, especially preventive measures have to be applied to keep the litter in good condition at any time. In case this could not be achieved, stocking densities should be decreased, e.g. by thinning.

There are no corrective measures for locomotory disorders. Once a bird is lame or has locomotory abnormalities, the birds should be separated in a sick pen to allow its recovery or humanly culled.

Broilers on floor systems with covered veranda

The hazards applicable in a floor with veranda system do not differ from the indoor only system (Tullo et al., 2017; Granquist et al., 2019). The risk factor of high humidity in the litter is higher due to the larger opening area towards the veranda. Other risk factors that are present in the floor housing system, such as insufficient space allowance per bird or heavy body weigh play a subordinate role since other genotypes are kept on lower stocking densities.

At the same time, the ventilation system could, e.g. switch from underpressure to equal pressure to minimise the incoming humid air (Mesa et al., 2017).

3.4.2.13. Predation stress

Description of WC, category of bird and husbandry systems

'Predation stress' was identified by the working group experts as a highly relevant welfare consequence for chickens for meat production kept on floor systems with free range and Chickens for meat production kept in mobile systems. A general definition of predation stress is presented in Table 5.

Predation stress occurs when an animal experiences stress and/or negative affective states such as fear and/or pain resulting from being attacked or perceiving a high predation risk. The use of an outdoor range is linked to higher risk of predation (Souillard et al., 2019; Jeni et al., 2021). Farmers will find kills of broilers and leftovers of kills in the outdoor range, and more seldom birds with injuries inflicted by a predator (Bestman and Bikker-Ouwejan, 2020). If the predator itself was not observed, sudden changes in behaviour (e.g. fewer birds on the range or birds staying closer to the popholes may reflect increased fearfulness) can be observed after a predator attack. Due to predation, the overall number of chickens in the housing system will decrease, although the data will only be apparent at the end of the rearing period, and negative alterations in performance data might reflect increased distress due to predation. Broilers, especially slower-growing ones, may also show piling behaviour due to panicking which may lead to increased mortality.

In France, predation has been estimated to be the cause of death in on average 6.3% (with a maximum of 34%) of broilers with outdoor access (Stahl et al., 2002). Limited knowledge exists on the effects of predation on welfare of broiler chickens. Obviously, the risk of mortality in the attacked birds is high, but also unsuccessful attacks may result in injuries, pain and suffering, as well as a risk of infection that may eventually cause death. The injuries may be inflicted either directly by the predator or indirectly due to smothering, i.e. panicking birds that pile on top of each other. Both successful and unsuccessful attacks elicit fear in the flock, and farmers report that predator attacks may cause a drop in egg production of laying hens, showing the significance of stress imposed on the birds. A similar impact may be expected for broiler chickens. A certain level of predator fear may be adaptive in free-range chickens. It has been shown that less fearful chickens range further away from the house (Lindholm et al., 2016; Stadig et al., 2017a) and it has been suggested that more fearful chickens need good cover of the range to make full use of the provided range area (Lindholm et al., 2016). Sufficient cover on the range such as trees, tall grasses or artificial shelter promotes range use and prevents chickens being attacked from aerial predators (Dal Bosco et al., 2014) (Stadig et al., 2017b).

Predation might be an event of only a few minutes but the risk for predation, and occasionally the single predation event itself, might impact the complete broilers lifespan. The severity is typically affecting only single broilers but might also sum up in high mortality rates in case of returning aerial predators or extensive attacks of ground predators. The prevalence is locally distinct.

Predation stress due to perceived predation also occurs in indoor systems but it was not retained as a highly relevant welfare consequence due to some other more highly relevant welfare consequences indoor.

Description, measurement, interpretation and characteristics of ABMs

Related ABMs are 'mortality due to predation' and 'fear response' (iceberg indicator see Section 3.4.2.21) that can increase due to stress related to predation or predation attempts.

Mortality due to predation

Definition	Number of birds found dead piled in a corner or killed or severely injured by the predator with the latter needing to be culled divided by the total number of birds present in the period considered.
Measurement	All carcasses and culled animals are classified into the categories: a. death caused by ground predator (e.g. fox), b. death caused by aerial predator (e.g. bird of prey), c. other (e.g. piled up). This categorisation helps to define the specific preventive/mitigative measures. Foxes usually decapitate the chicken and the carcass including feathers are gnawed. Birds of prey usually eat parts of the animal and pull feathers out. For categorisation, dead animals can be photographed for documentation (Bestman and Bikker-Ouwejan, 2020). Dead birds can be found either in a pile or with an abundance of lost feathers in the surrounding vicinity, because of a predator attack or a perceived attack. Often with visible wounds from the predator, but also inflicted after death by conspecifics. Decapitation, teeth marks and many feathers around the carcass, as well pilling up can be interpreted as injury or mortality due to predation. However, it cannot completely be excluded that the bird died for other reasons and then the carcass was later gnawed on by a predator, although this will be rare. It is more likely that the bird was injured or died for other reasons and then was later cannibalised by other broilers in the flock and this damage is mistaken for predation. An experienced person can distinguish between damage from a predator and damage from conspecifics.
Interpretation	The more dead or culled animals, the more predation stress experienced by the victims and potentially by the rest of the flock.
Sensitivity and Specificity	This ABM has high sensitivity since when predation stress is present mortality due to predation is likely to occur. This ABM has high specificity because in the absence of predation stress there is no mortality due to predation provided that the causes of mortality can be established.

Hazards and preventive and corrective measures

Insufficient fencing, e.g. no underground fence that can prevent foxes from digging under the fence (Moberly et al., 2004), and insufficient shelters (either artificial or vegetation) where the birds can seek protection (Dal Bosco et al., 2014) are major hazards. Inappropriate outdoor protection including vegetation as well as underdimensioned popholes especially for large flocks will increase the predation risk. The vegetation does not only offer protection. If the ground cover vegetation is negatively affected by bird's use or climate conditions, it may cause birds to range far from the barn and this in turn increases the risk of predation since large distances have to be covered to access fresh vegetation (Dal Bosco et al., 2014).

Concerning predators, three different measures are applied: prevention, deterrence and regulation. For example, lines of string (approximately 20 cm apart) can be placed above the outdoor area to prevent aerial predators to access from above. Gas cannons and flare guns may be fired at irregular intervals to deter predators. More sophisticated speaker devices exist that can detect sounds of predators in the area and emit adapted deterring sounds. Handheld lasers are also used to deter the predators. For some species of predators, a license to regulate the population by hunting may be obtained. Guarding animals such as herding dogs, donkeys, goats and llamas have been successfully integrated into the husbandry system (Beranger et al., 2007).

Providing natural shelters in terms of trees and tall grass stands has been reported to reduce mortality caused by predation in broilers (Dal Bosco et al., 2014; Stadig et al., 2017b). In laying hens, attacks by birds of prey were observed both under trees and in open areas (Bestman and Bikker-Ouwejan, 2020). In general, fox-proof fencing will prevent predation stress posed by foxes. To prevent attacks of aerial predators, shelters and large pophole dimensions are preferred, to allow quick return in the barn. Controlling the predator population might be one alternative, which has to be aligned with national legislation. It has been suggested that a certain level of fearfulness is adaptive in free-range chickens. Genotypes differ in level of fear, and this could be used to select the appropriate genotype for free range systems (Lindholm et al., 2016).

During the production cycle, more artificial shelter such as nets can be provided, as well as poles with moving objects such as cd's or clothes can be installed which can help to prevent attacks from aerial predators.

3.4.2.14. Restriction of movement

Description of WC, category of bird and husbandry system

'Restriction of movement' was identified by the working group experts as a highly relevant welfare consequence for chickens for meat production kept in floor systems, broiler breeders kept in individual cages, broiler breeders kept in collective cages. A general definition of 'restriction of movement' is given in Table 5.

Restriction of movement for broiler chickens and broiler breeders means that they are unable to move through the house or cage while they are motivated to do so. Broilers and broiler breeders might be restricted in their movement due to a high stocking density, inappropriate flooring, difficulties to access higher levels, lack of space, or locomotory disorders. A high number of chickens per square metre (high stocking density) also increases the risk for scratches when birds run over each other (Estevez, 2007). Limitations in movement might result in impaired leg health in broilers such as impaired bone strength leading to (leg) deformations (Reiter and Bessei, 2009) and impaired walking ability (Buijs et al., 2009; Bailie et al., 2018a). In addition, there is a risk for bad litter quality with high stocking density when the climate and litter management is inadequate, which increases the risk for all types of contact dermatitis and dirtiness of the feathers in broiler chickens (Buijs et al., 2009; Knierim, 2013; Petek et al., 2014). A high stocking density also increases the risk for scratches when birds run over each other. Vertical movements, e.g. on a second level platform, require additional ramps as fast-growing broiler chickens have difficulties to fly or jump due to their high bodyweight and morphology (Malchow et al., 2019a). Finally, locomotory disorders in itself restrict movement of broiler chickens (Weeks et al., 2000). Regarding broiler breeders kept in cages, the restriction of movement is depending on the space allocation in the cage. Even when the space allocation per bird is the same, the total space available for the bird will be greater in collective cages than in individual cages, although flying is not possible. Movement may also be affected by the design and location of the resources in furnished cages and cage flooring.

The duration of the restriction of movement depends on the reason. If it is caused by the housing system, such as in the case with breeders kept in cages, then it will persist for as long as the bird is housed in the cage. For broilers kept in floor systems, the stocking density may lead to restricted movement towards the end of the growth period or in the days before thinning a flock. For an individual with a locomotory disorder, the duration of the restricted movement will be for the time that the bird has the problem. The severity can also vary depending on the reason for the restriction, e.g. whether a locomotory disorder leads to an immobility of the chicken or whether stocking density and, therefore, space to move is limited. All breeders in cages will be affected, leading to a high prevalence of restricted movement in this husbandry system, and presumably all birds are affected by a high stocking density. The prevalence of birds with restricted movement caused by locomotory disorders will vary according to the underlying pathology and the management, as will the severity in this case.

Description, measurement, interpretation and characteristics of ABMs

Related ABMs are 'locomotory behaviour', 'wing flapping', as well as the iceberg indicators 'walking impairment', 'feather and body dirtiness', 'footpad dermatitis (FPD)', 'hock burn', 'wounds' (Section 3.4.2.21) for chickens for meat production and broiler breeders and 'stereotypic behaviour' (Section 3.4.2.21) for broiler breeders.

Locomotory behaviour

Definition	Self-propelled capacity to move from one place to another using leg and/or wing assisted movements that results in walking, running, jumping and flying activities (Liste et al., 2015) and excluding pacing.
Measurement	Analysis of locomotion can be performed by observing the locomotor activity: Directly observable: numbers of locomotor behaviours recorded in a sample of time observation, with direct observation of (a) predefined sample area(s) with an approximately average occupation of broilers. The observations are done during a specified time interval. Observable from video recordings: number of animals showing locomotor activity, either at a precise moment (scan) (e.g. de Jong and Gunnink, 2019) or during an observation period in an area of known size (e.g. Bailie and O'Connell, 2014). More recently techniques have been developed to automatically capture information on the broilers' locomotory behaviour, such as video imaging and RFID (van der Sluis et al., 2020; Yang et al., 2020; Gebhardt-Henrich et al., 2021).
Interpretation	The less the locomotory behaviour observed, the more the restriction of movement.
Sensitivity and Specificity	'Locomotory behaviour' is highly sensitive; when restriction of movement is present, it will reduce the locomotory behaviour. 'Locomotory behaviour' has low specificity. If there is no restriction of movement, other factors such as low light intensity or long light duration or wrong disposition of enrichment and lameness can decrease the locomotory behaviour of broiler chickens.

Wing flapping

Definition	Bilateral rapid upward and downward movement of the wings performed while standing still (Sokołowicz et al., 2020).
Measurement	Directly observable: numbers of wing flapping events recorded in a predefined observation period, with direct observation of a cage or part of the cage or a predefined area in the house for chickens for meat production kept in floor systems. Observable with video of a cage or part of the cage: number of wing flapping events during an observation period. For comparison, frequency of occurrences must be standardised by unit of time and number of birds observed. This behaviour is in any case happening from time to time and very brief, therefore sufficiently long observation time is needed (e.g. focal sampling, *ad libitum*).
Interpretation	With increasing space restriction, broiler chickens or broiler breeders will perform less wing flapping behaviour. An example from laying hens showed that space restricted laying hens in battery cages performed less wing flapping and had weaker bones than hens in systems with more space (Knowles and Broom, 1990).
Sensitivity and Specificity	The behaviour is highly sensitive as when space restriction is present the chicken will perform less wing flapping. 'Wing flapping' has low specificity. If there is no restriction of movement, 'wing flapping' can also be affected by other factors such as the ability to perform comfort behaviour. (Wood-Gush, 1972; Knowles and Broom, 1990; Gregory et al., 1991; Webster, 2004; Vanderhasselt et al., 2013; Gebhardt-Henrich et al., 2021).

Hazards and preventive and corrective measures

Stocking density has a direct influence on movement behaviour by creating open areas, and an indirect influence by affecting the health of the animals, especially regarding bad litter quality which may result in contact dermatitis impaired walking ability (Buijs et al., 2009; Mocz et al., 2022).

The absence or insufficient availability of elevated areas such as platforms or perches limits vertical movement of the broilers. In addition, if these are inappropriate for broiler chickens, e.g. because of the material (e.g. slippery) and shape of the perches (Pickel et al., 2010), this limits the possibility to use the structures. Accessibility of perches and platforms can be promoted by providing ramps to access the structures (Malchow et al., 2019a) or to adjust height with age of the broilers (Bailie et al., 2018b). Especially fast-growing genotypes have difficulties to access perches and for these types of chickens elevated platforms are preferred over perches (Malchow et al., 2019c).

Fast-growing genotypes might be restricted in their movement due to too heavy weights and morphology (relatively heavy breast weight). They have a higher risk of developing locomotory disorders than slower-growing chickens (Dixon, 2020; Rayner et al., 2020). Moreover, due to their high body weight, morphology and locomotor disorders they may have difficulties to jump on elevated areas such as perches or bales (Bailie et al., 2018a; Rayner et al., 2020).

Restriction of movement can be prevented by providing sufficient space per bird. With respect to space allowance, the proportion of chickens showing locomotory behaviour increases with increasing space allowance. A stocking density of about 10 kg/m^2 is considered not to limit the walking behaviour of broiler chickens (see Section 3.5.1.1 results of the EKE exercise). A higher space allowance also decreases the risk for locomotory disorders and for FPD and hock burn (see Section 3.5.1.1 results of the EKE exercise; Buijs et al. (2009)).

A slower-growing hybrid limits the risk for locomotory disorders and should therefore be used in broiler production systems. Moreover, these birds have a better balance of the body due to a relatively lower size of the breast as compared to fast-growing hybrids, which results in a better mobility of the chickens (Dixon, 2020; Rayner et al., 2020). These chickens are more able to access elevated structures as compared to fast-growing broiler hybrids (Rayner et al., 2020).

When providing elevated structures these should be designed in such a way that they are easy to access for the chickens and are comfortable. This can be done by adjusting the height to promote accessibility of perches, or to provide a ramp to access perches or platforms. Also, the material, being not slippery, and the shape in case of perches (promoting the grip) will stimulate accessibility. However, most research in relation to perch design has been carried out for layers. Fast-growing chickens prefer platforms to perches (Bailie et al., 2018b). Slower-growing hybrids are more able to use perches (Malchow et al., 2019c; de Jong et al., 2020).

When providing elevated structures, there should be a sufficiently large amount or area to enable the birds to use these when motivated. There is, however, a lack of research to provide guidelines on the minimal area that should be provided. The RSPCA advises 2.7 m perch per 1000 chickens (RSPCA, 2017), which is also applied in other enrichment programs (de Jong and Gunnink, 2019); however, this length of perches will not allow all birds to perch, and more research is needed to determine the amount of perch space needed for broiler chickens. Regarding elevated platforms, in studies on commercial farms platforms were provided for 10% of the floor area (Kaukonen et al., 2017a) or 6% of the floor area (Mocz et al., 2022). In a study on a commercial farm with platform areas of 13.8, 17.3 and 20.7 m^2 per 1000 chickens (equivalent to approximately 23 (minimum)–35 (maximum)% of the floor area), the highest area led to the highest proportion of roosting broilers.

Corrective and mitigative measures include thinning of a flock when the stocking density becomes too high. In case of deteriorating litter quality, adding fresh bedding or replacing the litter with fresh bedding to prevent severe footpad lesions and/or hock burn limiting the movement of the chickens. In case of infections causing locomotory disorders, veterinary treatment should be provided. In case perches are too high, perch height should be reduced to stimulate the use of perches or ramps should be provided.

The size, including the height, of the individual cage is clearly a major factor influencing the level of movement restriction. If the space allowance per bird is kept constant, birds in single cages can move much less than birds in collective cages because the total area is much smaller. The minimal size and height mean that resources that fulfil behavioural needs like an elevated perch (Olsson and Keeling, 2000), litter for dustbathing, a secluded nesting area are missing. Additionally, the small space does not allow for foraging and exploratory behaviour.

Resources included in the cage are usually limited in quantity, which may create competition between birds. The design may also influence the attractiveness of the resource. The smaller size of colony cages compared to floor systems means that there is less choice between nest box or perch locations. Furthermore, the density of animals and the resource themselves (or their distribution) may further restrict movement within the cage. There is a large body of literature on the design and allocation of resources in furnished cages for laying hens (EFSA AHAW Panel, 2023). Much of that knowledge can be expected to apply also to broiler breeders kept in furnished cages.

Restricted movement leads to heavier pullets (Purvis, 1978; Leeson and Summers, 1985) which is a health hazard in broiler breeders or leads to even more severe feed restriction.

Cages with larger areas restrict movement less, but it is unlikely to be feasible to increase the size of the cage to the extent necessary to eliminate the restriction of movement. Avoiding housing breeders in cages will prevent these welfare consequences from happening.

Larger areas restrict movement less, but it is unlikely to be feasible to increase the size of the collective cages to the extent necessary to eliminate restriction of movement. Criticism of the cage system *per se* has led the European Commission, being requested by the European Parliament, to consider a cage ban for laying hens. The use of cages for breeding birds is likely subject to the same criticism and should not be used. If they are used, the preference is for large cages with enrichment in the right disposition.

A corrective measure may be to add resources to the cage, e.g. perch, litter and nest box, but resources take up space. If cages are to be used, the most feasible corrective measure is to reduce the time that the bird is in the cage.

3.4.2.15. Resting problems

Description of WC, category of bird and husbandry system

'Resting problems' was identified by the working group experts as a highly relevant welfare consequence for day-old chicks hatched in hatcheries, Chickens for meat production kept in floor systems, Chickens for meat production kept on floor systems with covered veranda, Chickens for meat production kept on floor systems with free range, Chickens for meat production kept in mobile systems, Broiler breeders kept in individual cages, Broiler breeders kept in collective cages and Broiler breeders kept in floor systems. A general definition of 'resting problems' is given in Table 5.

Normal resting behaviour of a chicken is, under natural conditions, performed off the ground, e.g. in trees (Wood-Gush et al., 1978), and it is performed during the night as well as during daytime (Schrader and Malchow, 2020). However, during the first period of a chick's life, it will be brooded on the ground by the mother hen. Resting under a broody hen takes up a considerable proportion of the chick's time-budget during the first days of life (Sherry, 1981; Riber et al., 2007a). From approximately 7 days of age, a chick has acquired the physical skills to navigate three-dimensionally, and the mother hen will encourage them to perch (Riber et al., 2007b). From then on, resting is performed at least part time in an elevated position, i.e. off the ground.

Several studies have shown that resting is compromised in chicks hatched in hatcheries, where the hatchery procedures, transport and placement in the barn, typically lasting for 24–36 h, and never more than 72 h (when complying with the Council Regulation (EC) No 1/2005[6]), have been shown to be stressful for chicks and may have both short-term and long-term consequences on behaviour and stress reactivity (Hedlund et al., 2019; Jessen et al., 2021a).

In the typical intensive single-tier system used in broiler production, the broilers perform resting behaviour on the floor, as elevated structures, such as perches or platforms, are not available. In addition, due to the lack of structure in floor housing, there is no possibility to separate resting animals from active animals. Thus, when resting on the ground the broilers are often disturbed by conspecifics (Stamp Dawkins et al., 2004; Forslind et al., 2021). Birds walk over or close to resting conspecifics and thus cause them to get up or interrupt the resting phase (Yngvesson et al., 2017). This disturbance of resting birds is also due to the light-dark schedule that does not meet the requirements of especially young birds, which are often offered near to continuous or continuous light until day 7 that does not simulate the brooding cycle. This hampers synchronisation of rest and activity in flocks (Forslind et al., 2021). In addition, resting directly on the ground increases the risk of contact dermatitis and heat stress (Gebhardt-Henrich et al., 2017a; Tahamtani et al., 2020), although one study found no difference in contact dermatitis in broilers housed with or without access to platforms (Kaukonen et al., 2017a).

During the rearing period, broiler breeders of both sexes are typically kept in floor systems similar to those used for broiler chickens, i.e. without elevated structures. Birds are highly motivated to roost in an elevated area (Olsson and Keeling, 2002) and broiler breeders in rearing and lay are no exception (Gebhardt-Henrich et al., 2017b). For broiler breeders kept in cages, the integrated perches may not be perceived as satisfying the need for resting in elevated positions, as the perch is only elevated a few cm from the floor. The lack of perches has been shown to increase the fear level in broiler breeders (Brake et al., 1994). Furthermore, the high stocking density in cages in combination with perches being close to the floor leaves limited possibilities of resting undisturbed by active individuals.

Perches are used to some extent by broilers and frequently by broiler breeders, but especially broilers seem to prefer platforms, likely because the large breast makes balancing on the perch difficult (Norring et al., 2016; Gebhardt-Henrich et al., 2017b; Gebhardt-Henrich et al., 2018). Platforms are highly frequented by broilers from an early age throughout life, if access ramps are available (Bach et al., 2019; Forslind et al., 2021). When fast-growing broilers are offered perches, they are often only used very limitedly due to their high body weight and morphology, while slower-growing chickens are better able to make use of perches (de Jong et al., 2019, 2021; Bailie et al., 2018b). Both fast- and slower-growing hybrids make well use of elevated platforms, especially if access ramps are available (Malchow et al., 2019a).

Broilers (any system) and breeders reared in floor systems (pullets/males) will only rarely have access to elevated structures suitable for resting. The lack of elevated structures concerns the entire rearing period, i.e. the duration of resting problems is considerable. Similarly, caged broiler breeders will, throughout the laying period, only have access to perches that may not be perceived as such. Another factor contributing to the severity of the resting problems is the high stocking density, which accounts for all the animal categories, although more in the intensive systems, i.e. chickens for meat production kept in floor systems and any of the systems for broiler breeders.

Description, measurement, interpretation and characteristics of ABMs

Related ABMs to 'resting problems' are 'resting birds' and 'bird disturbance'.

Resting birds

Definition	The chicken rests with its head lowered or supported by the floor or body, eyes may be closed (Yngvesson et al., 2017).
Measurement	Counting the proportion of chickens showing resting behaviour.
Interpretation	If many chickens show resting, there is likely no resting problem. However, this depends on the period of the day and the age of the birds.
Sensitivity and Specificity	The ABM is highly sensitive, as if resting problems is present the proportion of resting birds will decrease. The ABM is highly specific, as if no resting problems are present resting chickens will be observed at a normal level. The percentage of resting day-old chicks has in one study been observed to be 12% and 61% for hatchery hatched and on-farm hatched chicks, respectively (unpublished data, de Jong). However, the proportion of chicks resting varies throughout the 24 h of the day due to the natural activity rhythm of chicks (Nielsen et al., 2008).

Bird disturbance

Definition	Physical contact between an active and a resting bird, causing the resting bird to change position and/or become more active (Cornetto et al., 2002).
Measurement	Observation of the behaviour of the chickens, when waiting in the hatchery, and within the final housing system. Disturbed birds usually vocalise, stand up in a sloping position, walk a short distance and lay down again. The disturbance is caused by the physical approach of another chicken and no other reasons. Scoring can be run via observational sampling methods but should take the location in the barn into consideration since studies showed that (1) wall are preferred resting places (Arnould et al., 2001; Buijs et al., 2010) and (2) bird disturbances are higher along the walls (Forslind et al., 2021). In turn, the level of disturbances varies between locations in the barn, which has to be considered during sampling.
Interpretation	The higher the occurrence of bird disturbances, the more severe the resting problems are.
Sensitivity and Specificity	The ABM is highly sensitive, as if birds are disturbing conspecifics and thereby causing resting problems, the proportion of resting birds will decrease. The ABM is highly specific, as in the absence of resting problems, few, if any, bird disturbances will be found.

Due to the speed of the conveyor belts, drops from belt to belt or in boxes and handling by humans (Knowles et al., 2004), it can be assumed that chicks are unable to rest during the hatchery procedures. During the holding period (i.e. waiting time in the hatchery, transportation and waiting time before placement in the barn), chicks may be unable to rest due to the repositioning of the racks, transportation movements and disturbances by conspecifics in the densely packed boxes (bird disturbance). However, it is difficult/impossible to count the number of resting chicks without disturbing them while in the boxes.

Hazards and preventive and corrective measures

Post-hatch handling and processing result in prolonged resting problems, not only during the handling and processing at the hatchery, during transport and placement in the barn, but also during the first day after being placed in the barn. A recent study showed that during the first 23 h after placement of hatchery chicks in the barn, the hatchery chicks rested less than chicks hatched on-farm (Jessen et al., 2021a), which may be due to a higher stress level experienced by the hatchery chicks. Furthermore, insufficient space allowance (e.g. in the boxes) causes disturbances by conspecifics, hindering proper rest. Inappropriate light management, i.e. constant light at high light intensities, may also be a hazard for resting problem.

In floor systems, there is disturbance by conspecifics (Forslind et al., 2021) since most of these systems do not give access to adequate and distinct resting places. Inappropriate light regime, such as (near to) continuous light for chickens until day 7, counteracts the synchronicity of the flock. High stocking densities, as well as environments which do not offer elevated structures, will increase the risk of disturbance. The absence of or insufficient availability of elevated elements, such as platforms, may cause frustration of the birds due to the lack of three-dimensional resting structures as well as competition. This, in turn, does not correspond to the requirement of an undisturbed resting phase in terms of animal welfare (Yngvesson et al., 2017).

Hazards are high stocking density, absence or low accessibility of elevated resting areas, and absence of a brooding light-dark cycle for chickens until day 14 of age and a relatively short dark period for older chickens.

In practice, floor systems with a covered veranda can be combined with a lower stocking density, environmental enrichment and windows (e.g. the Better Life one star system in the Netherlands (Vissers et al., 2019)). In these systems, the risk for disturbed resting may be reduced as compared to the floor housing only. Daylight, which is at least present in the covered veranda, may contribute to the circadian rhythm of the birds and, therefore, contributes to synchronisation of the flock with more birds sharing activities (and resting) at the same time (Bailie et al., 2013; Kumar et al., 2017; de Jong and Gunnink, 2019; Kumar et al., 2019), resulting in less disturbance of resting chickens.

Specifically for broiler breeders kept in furnished collective cages are insufficient perching space for the number of birds in the cage, or poorly located perches so that birds are disturbed while resting. Broiler breeders are bigger than laying hens and more space on perches means that more birds are able to rest on them simultaneously at night (Gebhardt-Henrich et al., 2017b).

3.4.2.16. Group stress

Description of WC, category of bird and husbandry system

'Group stress' was identified by the working group experts as a highly relevant welfare consequence for Chickens for meat production kept on floor systems Chickens for meat production kept on floor systems with covered veranda; Chickens for meat production kept on floor systems with free range; Broiler breeders kept in floor systems; Broiler breeders kept in multi-tier systems.

Group stress might not only be driven by stocking density but also by ontogeny. Especially when broilers are kept for a prolonged finishing period or, in general, for broiler breeders, the onset of sexual maturity might be crucial for interindividual contacts that may cause group stress. Sexual development of females starts around 18–20 weeks indicated by the onset of lay (McCartney, 1978; Lewis et al., 2007). In males, sexual maturity might already be developed around 11 weeks of life. This is close to or even within the finishing period of slower-growing broilers and may, therefore, cause increased group stress due to (hierarchical) aggression or resource allocation.

A general definition of 'group stress' is given in Table 5. This general definition of Group Stress mentions social hazards only – including a high incidence of aggressive and other types of negative social interactions (e.g. injurious pecking). Factors, such as high stocking density, uneven/insufficient resource allocation, are also likely to increase competition and social conflict, and this will increase the group stress. These factors should be considered as the hazards for group stress. Group stress can also result from other non-social welfare consequences in individual birds (predation stress or sensory overstimulation) subsequently transmitted socially throughout the flock. For example, an alarm call by one bird can produce fearful responses in others so increasing the group stress. Birds that are in pain, fearful or frustrated, from either social or non-social causes, are in turn more likely to resort to negative social interactions. Consequently, these situations can aggravate the hazard leading to group stress (pain may, e.g. result in an increase in defensive aggression). Group stress is impacted by feedback loop leading to negative affective states that can increase hazards leading to group stress. In other words, the indicator of group stress (e.g. alarm calls) may also be the cause of group stress (e.g. increased and prolonged arousal). Group stress is thus a complex concept, and it is important to understand the social dynamics of domestic fowl to understand what may go wrong.

Exposure to prolonged or severe negative social interactions may result in negative affective states such as pain, frustration, and fearfulness, indicated by changes in physiology, vocalisations, patterns of movement, or an increased level of fearful responses in standardised tests. Social stress due to conspecifics can also cause distress with physiological correlates, e.g. an elevated corticosterone level or other haematological indicators. Group stress may cause abnormal behaviours such as severe feather pecking and cannibalism. These behaviours by themselves may cause group stress as well.

Yet there are only few studies on social stress in broiler chickens, probably because it is difficult to track and reproduce in commercial farms with several thousand animals, in relation to the individual animal.

Specific stress situations might be applicable to systems including a veranda or outdoor area. Popholes will allow the birds to alternate between indoor and outdoor, but it might happen that dominant birds, as it is for all resources, might control popholes and access of others to the indoor or outdoor area as it was shown in laying hens (Campbell et al., 2018). Social groups use the outdoor areas together and the social structure becomes stronger with time (Campbell et al., 2018; Gómez et al., 2022) as it was shown in laying hens. This behaviour might prevail in slower-growing genotypes compared to fast-growing. Elevated structures might contribute to a reduction in stocking density and group stress as chickens may use these to get away from the group (Bach et al., 2019). Animals that can access different functional areas might be able to avoid aggressive interactions.

Measuring groups stress is difficult. There are some ABMs that may be affected by group stress but of these, none has a high specificity. The Qualitative Behavioural Assessment has initially been developed to measure the affective state of the flock, which might also be impacted by group stress. Although, the QBA has not been validated to measure group stress directly.

There are two major expressions of group stress; group stress caused by high stocking density and group stress developed during sexual maturity. The impact of stocking density might be present throughout the whole lifespan, whereas dominant or aggressive interactions develop during sexual maturity in slower-growing broilers and broiler breeders. The severity may result in individual losses due to high and prolonged stress levels, including the submissive bird to be kept away from resources. The prevalence is high due to high stocking densities applied in broiler production.

Description, measurement, interpretation and characteristics of ABMs

Related ABMs: 'fear response', 'plumage damage', 'piling and smothering', 'injurious pecking' (for all see Section 3.4.2.21) and 'aggressive interaction'.

If injurious pecking behaviours develop, it affects a greater number of birds. Social stress can also be reflected in change vocalisations. These indicators might be assessed digitally, but techniques are under development and not yet implemented in practice. Increased fearfulness can be measured by the duration of fear responses such as tonic immobility and by the response in a startle test, although other factors may also impact test responses. Although even being not so common in broiler breeders, piling can also occur in response to a fearful stimulus. When males and females are kept together, there is an increased risk of wounds caused by males to the females.

Aggressive interactions

Definition	Aggressive interactions between birds are predominantly shown by negative physical contact (pecking kicking, fighting) or a dominant bird chasing a submissive bird. Both birds are in direct physical contact, injuries might but not necessarily occur (Baxter et al., 2019).
Measurement	Aggressive interactions might be observed directly, e.g. using behavioural sampling techniques. For comparison, frequency of occurrences must be standardised by unit of time and number of birds observed.
Interpretation	Ongoing aggression, beside the (short) time period needed to, e.g. establish a pecking order in small flocks, has detrimental effects on the individual. In addition, prolonged aggressive interactions might stress the whole flock which in turn reduces the stimulus

	threshold of the entire flock resulting in chronic social distress. The more aggressive interactions, the lower the welfare for the victims (Riber et al., 2017).
Sensitivity and Specificity	The ABM is highly sensitive, as if group stress is present the frequency of aggressive interactions will increase. The ABM is highly specific, as when no group stress is present the likelihood for aggressive interactions is low.

Hazards and preventive and corrective measures

Especially underdimensioned resources will cause group stress as specific resources might be preferred and birds that are more dominant might prevent access to subordinate birds. This also includes popholes to the covered veranda which have been found to be occupied by birds limiting the access of others (Göransson et al., 2021). Although, agonistic behaviours were not increased among the birds crowding the popholes. In general, the risk of unequal resource allocation (e.g. water and feeding troughs) will increase with increasing stocking density, especially among slower-growing hybrids. In case these hybrids reach maturity (around 17 weeks or even earlier), group stress will increase based on aggressive and dominant interactions between males.

Slower-growing hybrids (see glossary) typically used in floor systems with covered veranda or floor systems with free range are more active and agile, therefore competition over limited resources is more likely to occur, causing group stress. These hybrids may also require lower stocking densities and higher space allowance per bird, respectively, due to increased activity as the outdoor access may be restricted to daytime and not to the indoor light regime.

The main hazards for group stress are related to high stocking densities (Spinu et al., 2003) and large group sizes. Increasing space allowance could be reached by thinning within the production period or decreasing stocking densities form day one.

The size of the group can also be a hazard but it not as simple as larger groups experience more group stress, since once the number of birds is above a level where a dominance hierarchy can be maintained, flocks seem to move to another social organisation (Estevez et al., 2003). This is further confounded if there is an underdimensioned allocation of resources, which can lead to competition for physical resources in the environment, e.g. space, feed water as specific resources might be preferred, and more dominant birds might prevent access to subordinate birds. This also includes the popholes to the covered veranda. An inappropriate ratio of males to females or level of maturity of the two sexes can also contribute to group stress. Since social behaviour has a genetic component, the genetic predisposition of the birds to group stress is also a potential hazard.

There can also be differences between breeds or lines of breeders in their predisposition to experience social stress (for laying hens; e.g. Birkl et al., 2017).

The match of the selected hybrid, and the environment given for production (here outdoor access) is important to prevent group stress (Evaris et al., 2019). As for the floor housing with covered veranda, large accessible popholes, sufficient resources in terms of food and water supply as well as retreats (no dead ends) will allow birds to avoid each other (Tahamtani et al., 2018b; Baxter et al., 2020). As slower-growing birds are more agile, resources may have to be adjusted and offered at levels exceeding the minimum legal requirements (Sarıca et al., 2022). Environmental enrichment, including the outdoor area, promotes birds to exhibit foraging and explorative behaviours and reduces the risk of social stress, including feather pecking and cannibalism (Rodenburg et al., 2013). These stereotypical behaviours may be triggered by frustration and the inability to act out ethological needs. Sufficient interindividual distances will be supported by higher space allowance per bird and lower stocking density, respectively.

Even if the group size remains the same, structures like panels can enable birds to hide and prevent group stress and aggression in broiler breeders (Leone and Estévez, 2008). Elevated platforms can make it easier for birds to escape aggressive behaviour and can be especially important for low-ranking birds. Some systems separate the males from the females for parts of the day, which has been called the 'Quality time concept' (van Emous, 2010). Genetic selection to reduce aggressiveness in males or breeding strategies that include selection in groups can also help reduce problems with social stress.

Rearing birds so that they are well prepared to move around in this system, and so avoid negative social interactions, is important. Providing sufficient resources and distributing them appropriately will also reduce competition between individuals.

The free-range area should be attractive in terms of vegetation (or additional food sources) as also be safe for the birds as the use of the free-range area lowers stocking density and, therefore, group stress within the barn.

Temporarily decreasing light intensity may reduce feather pecking and cannibalism and so reduce group stress.

3.4.2.17. Soft tissue lesions and integument damage

Description of WC, category of bird and husbandry system

The welfare consequence 'soft tissue lesions and integument damage' was identified by the working group experts as a highly relevant welfare consequence for: Chickens for meat production kept in floor systems; Chickens for meat production kept on floor systems with covered veranda; Chickens for meat production kept on floor systems with free range; Broiler breeders kept in individual cages; Broiler breeders kept in collective cages; Broiler breeders kept in floor systems and Broiler breeders kept in multi-tier systems. A general definition of 'soft tissue lesions and integument damage' is given in Table 5.

Pododermatitis and hock burn will be the most common health-related problems (Hocking and Veldkamp, 2019). Scratches as well as irritation or inflammation and blisters of the breast skin might also be found (Dinev et al., 2019) although breast blisters and breast irritation seem not to be very prevalent nowadays (e.g. de Jong et al., 2022). In breeding birds kept in cages, there may be damage to the feet caused by standing on the wire floor for long periods of time, and toes or nails may become trapped resulting in toe injuries. In the event of feather pecking (more found in slower growing hybrids that reach older ages or breeding birds), also wounds in the skin can be found with the possibility to develop into cannibalism. Cellulitis is also a prevalent problem in broiler chickens and a reason for carcass condemnation (Norton, 1997). Wounds on the back of the neck and head in females, caused by males when mounting to mate, are seen in flocks with natural mating. Mutilations, such as beak trimming in both males and females, and removal of one or more claws in the males (Riber, 2017) are also forms of soft tissues lesions and integument damage, even if the intention is to reduce lesions and damage caused by one bird to another. Most of the work on these soft tissue lesions and integument damage is on broilers, with rather little work on breeding birds. The issues and underlying causes, however, are similar.

Pododermatitis and hock burn are the most relevant welfare indicators used at the processing plant to reflect the level of welfare of birds on farm. Automated measures using computer vision are applied in some countries (Section 3.12), although, the results will have no impact on the past flocks but might increase welfare through management procedures in the upcoming flocks. FPD as well as hock burn are common in floor housing systems, mainly because of inappropriate litter management or general health problems. Different bedding materials can help reduce the problem (Kaukonen et al., 2017a) as well as nutritive supplements (Kim et al., 2017; Abraham et al., 2021). In broiler breeders a correlation has been shown between the presence of footpad lesions and systemic bacterial infections with Gram-positive cocci in broiler breeder birds (Thøfner et al., 2019).

For the breast skin, it is necessary to distinguish between blisters (bursitis), buttons (dermatitis), and breast burns (inflammation). These are less common than pododermatitis, although economically more severe as they lead to the carcass being discarded (Hocking and Veldkamp, 2019). These abnormalities develop when the bird has frequent or constant contact of its feather-less breast with the bedding material with high moisture. Heavy and inactive birds that lie on the floor are prone to breast blisters. Poor litter quality can favour breast alterations (Li et al., 2017), which should be differentiated into the above-mentioned categories; blisters, buttons and breast burns (Souza et al., 2018a).

Scratches are caused by other birds walking across lying birds and mainly found on the back of the animal (Villarroel et al., 2018). Scratches appear to be correlated first with stocking density and temperature, and they are ports of entry for other pathogens, as well as being negatively related to economics and bird welfare (Alfifi et al., 2020). In breeders, scratches on the back of females can occur during mating. Skin injuries can occasionally be caused by equipment, but bruising is more common. For example, flight responses as fear response may lead to birds moving in uncontrolled ways in the barn. In an aviary system, birds may also fall from (and crash into) perches or tiers as they move in the system.

Cellulitis is characterised by discoloration and thickening of the skin and inflammation of the subcutaneous tissues. While not the only bacterium isolated from the lesions, *Escherichia coli* are by far the most frequent and abundant. Few, if any, clinical signs are observed in affected birds and usually the condition is not detected until the birds are processed (Messier et al., 1993). Many management factors influence the occurrence of cellulitis in broiler chickens including the source of the breeders (Schulze Bernd et al., 2020).

The main types of soft tissue lesions and integument damage, if not infected, will eventually heal after some weeks. The exception might be the different types of dermatitis, which, once developed, generally persist until slaughter. The duration of the welfare consequence, however, may still represent a large portion of the bird's life. The severity of the welfare consequence and their prevalence will vary between flocks, being influenced by the quality of the management. Higher stocking densities for broilers can lead to a higher prevalence of types of dermatitis, whereas scratches may be more prevalent in breeders.

Description, measurement, interpretation and characteristics of ABMs

ABMs to measure 'soft tissue lesions and integument damage' are 'wounds' (Section 3.4.2.21), 'breast blisters', 'breast burns', 'bruises', 'cellulitis', 'footpad dermatitis (FPD)' (Section 3.4.2.21), 'plumage damage' (Section 3.4.2.21), 'hock burn' (Section 3.4.2.21), 'injurious pecking' (Section 3.4.2.21).

Breast blisters

Definition	A breast blister (or keel cyst) is an enlargement of the sternal bursa, appearing as a swollen, liquid filled cyst on the centre of the breast bone and varying in colour from white over red to blue or black (Nielsen, 2004). Breast blisters are assumedly caused by prolonged pressure or friction on the keel bone, leading to a fluid-filled swelling of the bursa (Miner and Smart, 1975). Breast blisters are predominantly found in broiler breeders and might also appear in slower-growing chickens.
Measurement	Breast blisters can be visually assessed and scored, e.g. on a 3-point scale with a score 0 being no blister, a score 1 mild blisters (small and colourless blisters) and a score 2 severe blisters (large or dark coloured blister) (Nielsen, 2004).
Interpretation	The more the pressure on the breast, the higher the risk of breast blisters.
Sensitivity and Specificity	Breast blisters are rare in broiler flocks (Kaukonen et al., 2016). Breast blisters in slower-growing broilers are mainly influenced by the type of floor, hybrid and type of perches (Nielsen, 2004). The ABM has low sensitivity, as breast blisters are not always present when there is soft tissue and integument damage. The specificity of breast blisters is high, as when there is no soft tissue and integument damage there will be no breast blisters present.

Breast burn

Definition	Inflammations of the breast skin are often called breast burn. These alterations especially in the colour of the skin due to erythema belong also to the category of contact dermatitis. Breast burns will predominantly be found in fast-growing broilers.
Measurement	Souza et al. (2018b) described a visual scoring system according to which breast burns can be scored as 0 (absence); 1 (light) with the broiler showing slightly pink areas on the breast skin, often locally definable; 2 (moderate) with the broiler's skin showing different grades of erythema which also may vary in colour from dark pink to red; 3 (severe) with the broilers breast skin being altered in the colour due to large inflammations. Dark spots (local severe contact dermatitis) might be found.
Interpretation	The poorer the quality of the litter, the higher the risk for an inflammation of the breast skin.
Sensitivity and Specificity	Breast burns are frequently found in broiler flocks (Kaukonen et al., 2016). The ABM has low sensitivity, as breast burns are not always present when there is soft tissue and integument damage. (Nielsen, 2004). The specificity of breast burns is high, as when there is no soft tissue and integument damage there will be no breast burns present.

Bruises

Definition	Bruising is a superficial injury that occurs after trauma. It results from a haematoma and is often without rupture of the skin (Cockram et al., 2020).
Measurement	Assessment of the skin of the chicken, either ante-mortem or post-mortem in order to score prevalence of bruises, including their extent (Nijdam et al., 2004) and/or colour (Northcutt et al., 2000). The presence and severity (extent and colour) of a bruise can be detected at the abattoir using automatic technology based on images (Langkabel et al., 2015). Recent bruising appears red; between 12 and 24 h after trauma, the breast bruises often become dark red to purple, whereas leg and wing bruises become lighter. Bruising that occurs during rearing can potentially be identified by a green colouration that occurs 24–48 h after trauma (Cockram et al., 2020).
Interpretation	The more physical trauma to the chicken, the more bruises.
Sensitivity and Specificity	The ABM has low sensitivity, as bruises are only one type of soft tissue lesions and integument damage. The ABM has high specificity, as when there are no soft tissue lesions and integument damage, no bruise will be present.

Cellulitis

Definition	Discoloration and thickening of the skin and inflammation of the subcutaneous tissues caused by an *Escherichia coli* or other infections (Derakhshanfar and Ghanbarpour, 2002).
Measurement	Post-mortem examinations of the skin and bacteriological examinations (Messier et al., 1993). Damages to the skin may become the entry point of the *E. coli* infection causing cellulitis, i.e. when the cellulitis is present it is preceded by skin damage.
Interpretation	The more *E. coli* present in the barn and the more damages to the skin, the more cellulitis.
Sensitivity and Specificity	The ABM has low sensitivity, as cellulitis is not always present when there is soft tissue lesions and integument damage. The ABM has high specificity, as when soft tissue lesions and integument damage is absent it is likely that there will be no cellulitis. This includes that there has not been earlier soft tissue and integument damage, now healed, that might have been the entry point for infection.

Hazards and preventive and corrective measures

The prevalence of pododermatitis and hock burn, as well as the other forms of dermatitis, are correlated to the management of the bedding material to maintain a good litter quality (Hunter et al., 2017; Hocking and Veldkamp, 2019). Litter of an inappropriate quality, especially with a high moisture, may cause FPD. This might be specifically reasonable in systems with access to an outdoor area, although covered, as under unfavourable weather conditions more humidity will be transported into the barn (Hunter et al., 2017). Outdoor areas that are too wet may cause contact dermatitis on the feet, hock and breast. As many birds want to go outside at the same time and the activity level might increase, some studies report more scratches in veranda systems (inappropriate resources, undersized popholes, technopathy). In addition, litter humidity might be affected due to large popholes and inflowing air. If birds stay close to the barn due to lack of cover or other management factors, the ground may get condensed, allowing less water to seep away and resulting in birds with prolonged contact to wet and contaminated soil. Insufficient space allowance per bird might be applicable during nighttime in case of increased indoor stocking densities.

Also, high stocking densities have been found to be a risk for contact dermatitis, which has been related to the adverse effect on litter quality. Moreover, high stocking densities are a risk for disturbance of resting birds, which may cause skin scratches because of birds running over each other. Furnishing in the broiler house may cause technopathies. A technopathy occurs when sharp edges, e.g. at food troughs, perches or other places frequently approached by the broiler cause an abrasion of the feathers or even injuries, e.g. of the skin. The part of the body where the technopathy is found may indicate the causes in the housing (Spieß et al., 2022a).

There may be different predispositions developing FPD in different hybrids. Slower-growing broiler chickens have a lower risk of developing contact dermatitis as compared to fast-growing hybrids (Dixon, 2020; Rayner et al., 2020). Insufficient resources, insufficient platform area, or insufficient perch length (for platforms and perches, respectively) may result in scratches due to birds running over each other to reach the resources.

Broiler breeders

In broiler breeders housed in individual cages, the main hazards for foot lesions are the quality of the wire floor and the amount of time the bird is standing on it. It is also important that there are no places where the claws of the bird can be trapped. The design of the sides of the cage and the height and ease of access to the food trough are the main hazards for plumage damage in individual cages. If broiler breeders are kept in cages, the length of time the bird is in the cage should be as short as possible. The cage floor, sides and feed trough should be designed to minimise skin lesions and integument damage.

In broiler breeders housed in collective cages, the main hazards for feather pecking are the absence of litter and high stocking density. The design of the sides and the height of the cage and ease of access to the food trough are the main hazards for abrasive damage to the plumage. The main hazards for foot lesions are the quality of the wire floor and the quality of the litter, in combination with the duration of time the bird is standing on that type of floor. It is also important that there are no places where the claws of the bird can be trapped. In addition, rearing birds with perches or elevated platforms can be expected to increase the use of the elevated areas.

In broiler breeders in floor housing, high body mass and wet and soiled litter result in different types of dermatitis. Thus, the main hazards are too little and poor litter quality, a high stocking density which makes it more difficult to manage the litter, and a lack of elevated areas where birds can get up of the litter. On the other hand, the main hazards for bruises and wounds are rough mating and male/female aggression. Missing feathers particularly on the back due to feather pecking or overmating are a risk for skin lesions and wounds occurring during the copulation.

In broiler breeders kept in multi-tier systems, birds using the elevated areas will spend correspondingly less time in contact with the litter. Multi-tier systems are more complex than floor systems, which has both advantages and disadvantages regarding wounds and scratches. Although generally rare, wounds caused by the system itself may be more common in multi-tier systems than in floor systems, whereas wounds and scratches caused by conspecifics, which are more likely anyway, may be lower in multi-tier systems than in floor systems since females can escape males by jumping up in a multi-tier system.

In broiler breeders kept in multi-tier systems, replacing litter that is wet and soiled and introducing features like raised perches or partition to reduce the interactions between birds. Genetic selection for males showing less rough mating behaviour and aggression may also help.

In broilers kept on floor systems, having litter that is dry and friable is the basic prevention for contact dermatitis (Hunter et al., 2017; Marušić et al., 2019; Monckton et al., 2020b). There are various factors that can be controlled to keep the litter in a good condition: the climate in the house, the litter type and light schedule (de Jong and van Harn, 2012). Further, slower-growing broiler hybrids have a lower risk to develop contact dermatitis. In addition, the equipment must be designed so that it does not cause any injuries to the birds, by ensuring there are no sharp edges and birds cannot become trapped. A reduced stocking density will prevent disturbance of resting birds and thus scratches. Sufficient number of resources will prevent scratches caused by competition for resources.

De-spurring and de-toeing prevent skin lesions and wounds during mating but is a welfare consequence for males in its own. The use of panels to separate birds and elevated structures will reduce damage from interactions with conspecific as will separating the males and females for part of the day.

Broilers

In broilers kept in floor housing with covered veranda, the provision of appropriate and wide popholes to allow many birds to alternate between indoors and outdoors might lower the risk of scratches. There are other preventive and corrective measures such as litter management for example.

In broilers kept with free range, sufficient sized popholes, and good litter quality indoor as well as soil management outside is conducive. In some farms, the area close to the barn is covered with bark mulch or other drying material. Lowering stocking density and/or re-scattering of bedding material may be additional options.

Avoiding overweight animals will promote activity and help prevent FPD and breast blisters. Proper litter management is also important in this respect.

For broilers kept in floor, once contact dermatitis has developed, it is difficult to envisage any corrective or mitigative measures within the lifetime of the bird.

3.4.2.18. Umbilical disorders

Description of WC, category of bird and husbandry system

'Umbilical disorders' was identified as a highly relevant welfare consequence for: day-old chicks hatched on farm.

A general definition of 'umbilical disorders' is given in Table 5. During incubation, the developing embryo receives nutrients from the yolk, which is surrounded by a highly vascularised membrane, i.e. the yolk sac (Romanoff, 1960). At approximately the time when the eggs are moved to the hatcher or farm for on-farm hatching to occur, i.e. embryonic day 18, the yolk sac will start to become absorbed via the navel into the body cavity of the embryo. By the time of hatching, the yolk sac is supposed to be fully withdrawn and the navel and surrounding area should be closed and healed (Romanoff, 1960). However, chicks may hatch with unabsorbed yolk sacs, preventing healing of the navel to different degrees, which can be observed as smearing of downs with albumen (i.e. leaky navels), discoloration of the skin surrounding the navel, navel buttons (i.e. scab formed over the navels) and open navels (Fasenko and O'Dea, 2008). As there is no systematic sorting of chicks hatched on farm, some chicks might start their rearing period experiencing this welfare consequence.

Studies have reported unhealed navels and enlarged yolk sacs to be the abnormalities most frequently registered during chick quality assessment of both on-farm and hatchery-hatched chicks, but with a higher prevalence in chicks hatched on-farm (van de Ven et al., 2012; de Jong et al., 2019; Jessen et al., 2021b). For example, Jessen et al. (2021b) reported unhealed navels to occur in 8.2% of the chicks hatched on-farm, whereas the prevalence was 5.3% for the hatchery-hatched chicks. The severity of unhealed navels of newly hatched chicks can be considered high, as it may result in mortality, mainly during the first week of life, which is likely due to the open navel being the entry point of pathogenic bacteria leading to infection (Fasenko and O'Dea, 2008). In addition to increased mortality, secondary infections may also cause pain to the chicks that may last for a prolonged period.

However, none of the studies comparing on-farm and hatchery-hatched chicks reported an increased mortality in the former – contrarily all of them found either a lower or similar first week and total mortality in the chicks hatched on-farm compared to hatchery-hatched chicks (van de Ven et al., 2012; de Jong et al., 2019; Jessen et al., 2021b). Some studies have reported no or limited evidence of a relationship between chick quality assessments and performance or mortality (Willemsen et al., 2008; van de Ven et al., 2012).

Description, measurement, interpretation and characteristics of ABMs

'Navel condition' is the ABM for 'umbilical disorders'.

Navel condition

Definition	The stage of healing of the navel in day-old chicks, including complications revealed as remnants of yolk, smearing of downs with albumen (i.e. leaky navels), discoloration of the skin surrounding the navel, navel buttons (i.e. scab formed over the navels) and open navels (Fasenko and O'Dea, 2008).
Measurement	A clinical examination of the navel allows an assessment of the navel condition. This is included in many of the qualitative methods used for assessing chick quality, such as the Pasgar and Tona scores (Boerjan, 2002; Tona et al., 2003) in which detailed descriptions of scoring protocols can be found.
Interpretation	The poorer the navel conditions, the more umbilical disorders.
Sensitivity and Specificity	The ABM has high sensitivity, as when there is umbilical disorder it is highly likely that there will be unhealed navel condition. The ABM has high specificity, as a chick with no umbilical disorder will show normal navel condition.

Hazards and preventive and corrective measures

Heat stress during incubation (i.e. egg-shell temperatures above 37.8°C), particularly during the last week, may result in poor chick quality due to poorly absorbed yolk sacs, leading to unhealed navels (Du Preez, 2007; Hamidu et al., 2018; van der Wagt et al., 2020). Therefore, the risk of umbilical disorders may be higher for chicks hatched on-farm compared to those hatched in hatchery facilities, as it is more problematic to delicately manage the microclimate during transport on day 18 of incubation and the following hatching period on the farm, which increases the risk of suboptimal temperature and humidity conditions. Indeed, farmers have reported such incidences, whereas this has never been documented in scientific studies. Few studies have investigated effects of a lower incubation temperature (< 37.8°C) on embryonic development, and remarkably, egg-shell temperatures of 36.7°C from embryonic day 19 onward (Maatjens et al., 2014) and 35.6°C or 36.7°C from embryonic day 15 onward (Maatjens et al., 2016) did not affect residual yolk weight at hatching compared with an egg-shell temperature of 37.8°C, meaning that low incubation temperature is not a prominent risk factor of umbilical disorders.

Insufficient sorting of second-grade chicks, which include chicks with umbilical disorders, due to the suboptimal conditions for examining the newly hatched chicks on-farm may be a risk for chick welfare when hatching chicks on-farm. Studies have shown that fewer chicks are sorted as being second grade when hatching on-farm (see Jessen et al. (2021b)), but whether this is due to fewer being identified (i.e. second-grade chicks are overlooked) or whether the occurrence of second-grade chicks is lower remains unanswered.

As umbilical disorders are caused by too high incubation temperatures, particularly in the last week of incubation, careful management of the microclimate during transport of the eggs at embryonic day 18, and on the farm, is essential to keep the eggshell temperature below 37.8°C and prevent this welfare consequence.

If the egg-shell temperature rises above 37.8°C, the environmental conditions should be adjusted to restore egg-shell temperatures below 37.8°C, i.e. reducing environmental temperature and/or increasing the ventilation rate.

Second-grade chicks showing umbilical disorders either should be euthanised or placed in sick pens with extra surveillance.

3.4.2.19. Inability to avoid unwanted sexual behaviour

Description of WC, category of bird and husbandry system

'Inability to avoid unwanted sexual behaviour' was identified by the working group experts as a highly relevant welfare consequence for: Broiler breeders kept in collective cages (when males are housed with females), kept in floor systems and kept in multi-tier systems. A general definition of 'inability to avoid unwanted sexual behaviour' is given in Table 5.

If females want to mate, they crouch at the approach of the male to facilitate mounting of the male. In the case that females try to avoid unwanted sexually behaviour they flee when the male approaches or struggle in case the male tries to mount them. A copulation under such circumstances would be a forced copulation leading to stress in the female. The extent of unwanted sexual behaviour seems to vary between hybrids of birds and is influenced by the relative ages of the females and males (Millman et al., 2000; Millman and Duncan, 2000). Male birds that have sexually matured earlier than the females may subject them to forced mating (Millman et al., 2000; Gebhardt-Henrich et al., 2020). There also seems to have been a decrease in courtship behaviour in the males which is mirrored in a decrease in the normal sexual crouching shown by females (Millman et al., 2000; de Jong et al., 2009; Gebhardt-Henrich et al., 2020). This lack of courtship behaviour may have been an indirect consequence of selection for increased copulatory behaviour and fertility in males. Overmating (too frequent mating) may lead to feather loss on the back and wings, i.e. plumage damage. Once feathers are missing and the bare skin is exposed, skin lesions (like scratches and wounds at the back of the neck and head) of the females from mounting males become more likely because of the damage from the feet and claws of the male (Estevez, 1999; de Jong and Guemene, 2011). Female birds also receive injuries to the head and necks, as a result of pulling against the peck of the male, and they also have more injuries on their back and wings, as a result of the damage from the feet and claws of the male (Estevez, 1999; de Jong and Guemene, 2011). On dwarfed females, mounting of the males might be more difficult due to the size dimorphism and males may scratch the females and cause lesions. Alternatively, the male might stand on the ground during copulation instead on the back of the female, which is better for the female. Nevertheless, hybrids with a large sexual dimorphism in size may also cause fear in the dwarfed females because of much larger males (e.g. in the Sasso breed, (Gebhardt-Henrich et al., 2020)). A further consequence in flocks with a high level of unwanted sexual behaviour is that females in floor systems and multi-tier systems may hide in nests and so may not be able to access the other resources. This is not possible in collective cages. In collective cages, females have no means to avoid aggressive males, which aggravates this welfare consequence compared with non-cage systems, where they can escape.

A further consequence in flocks with a high level of unwanted sexual behaviour is that females in floor systems and multi-tier systems may hide in nests and so may not be able to access the other resources. This is not possible in collective cages. In collective cages, females have no means to avoid aggressive males, which aggravates this welfare consequence compared with non-cage systems, where they can escape.

The welfare consequence 'inability to avoid unwanted sexual behaviour' can be most severe at the age when males and females are mixed because males might mature at an earlier time than females. In that case, the males should be introduced gradually (handbook Aviagen, 2018b). However, the inability to avoid unwanted sexual behaviour lasts throughout production and can increase in severity after spiking (introduction of young males) (but see (Chung et al., 2012)). The severity of this welfare consequence differs among females because some are more preferred by males than others are. The females (Gebhardt-Henrich et al., 2020). The severity of this welfare consequence also depends on the sex ratio. When overmating is present (e.g. plumage damage in females) the sex ratio has to be adjusted by removing males (handbook Aviagen, 2018b). As male broiler breeders are selected for frequent mating, lack courtship behaviour, and tend to be aggressive towards females, this welfare consequence is often severe and affects the majority of females (Millman et al., 2000; Millman and Duncan, 2000; de Jong et al., 2009; de Jong and Guemene, 2011). The extent of unwanted sexual behaviour varies between hybrids of birds and is influenced by the relative ages of the females and males (Millman et al., 2000; Millman and Duncan, 2000). Male birds that have sexually matured earlier than the females may subject them to forced mating (Estevez, 1999). There also seems to have been a decrease in courtship behaviour in the male broiler breeders which is mirrored in a decrease in the normal sexual crouching shown by females (de Jong et al., 2009). This lack of courtship behaviour may have been an indirect consequence of selection for increased copulatory behaviour and fertility in males. Overmating (too frequent mating) may lead to feather loss on the back, i.e. plumage damage. Once feathers are missing and the bare skin is exposed, skin lesions (like scratches and wounds at the back of the neck and head) of the females from mounting males become more likely. Female birds receive injuries to the head and necks, as a result of pulling against the pecks of the male, and they also have injuries on their back and wings, as a result of the damage from the feet and claws of the male (de Jong and Guemene, 2011). A further consequence in flocks with a high level of unwanted sexual behaviour is that females may hide in nests and therefore are not able to access the other resources. This is less likely in furnished cages with a limited nest space compared to floor systems with nestboxes.

The situation in floor housing resembles the situation in collective/furnished cages where males and females are kept in a ratio of one male for 10–12 females. In contrast to furnished cages, in floor housing, the sexes can separate to a certain extent and while males predominantly stay in the litter area, females can stay away from the litter area to avoid males. However, males are flexible about where to mate and can follow the females everywhere so females cannot avoid copulations. When hens are mostly present on the slats most copulations happen there. Females on perches were seen to be dragged down by a male and then subsequently mated with by several males (Gebhardt-Henrich et al., 2020). The litter is a resource that both sexes should be able to use. However, the few females that use the litter area are exposed to forced copulations (Leone and Estévez, 2008). Although perches (and aviary tiers) do not lead to a reduction of copulations, they may lead to a higher acceptance of mating by females, i.e. less struggling by the hen during copulations (Gebhardt-Henrich et al., 2020).

Description, measurement, interpretation and characteristics of ABMs

ABMs for 'inability to avoid unwanted sexual behaviour' are 'wounds' (Section 3.4.2.21), 'forced copulations', 'avoidance of the litter area by the females', 'plumage damage' (Section 3.4.2.21).

Forced copulations

Definition	Mating where the female struggles to escape instead of crouching when the male mounts and copulates (de Jong et al., 2009).
Measurement	Direct observations of the flock or video observations of the litter where most mating activity takes place in floor and multi-tier systems. In cages, mating take place everywhere. Mating take place during the light day outside feeding times. The female often vocalises during the struggle (Millman et al., 2000) which will be counted per time unit or per copulation. Observation should not take place during feeding times. The observation period must be long enough to observe a couple of mating.

Interpretation	Aggressive behaviour of males towards females in the context of copulations provokes fear and pain due to inability to avoid unwanted sexual behaviour and injuries. The more aggressive behaviour of males towards females during copulation, the more the inability to avoid unwanted sexual behaviour by females.
Sensitivity and Specificity	The behaviour is highly sensitive since if the welfare consequence is present, forced copulation will be present. This ABM is highly specific since if the welfare consequence is not present, no forced copulation will be seen.

Avoidance of the litter area by the females

Definition	Males are predominantly on the litter and females avoid the litter area including the feeder line for females on the litter (Gebhardt-Henrich et al., 2017b).
Measurement	Direct observation of proportion of females on the litter area. This can be done by counting birds on the litter and on the slats from video recordings. Direct observations might be less helpful because the presence of a person might influence the distribution of the birds in the barn.
Interpretation	Due to aggressive behaviour of males and because the hens try to avoid unwanted sexual behaviour, the hens stay on the slats and do not feed from the feeder line on the litter and therefore can suffer from other welfare consequences such as 'prolonged hunger'. The more the females are away from the litter area, the more inability to avoid unwanted sexual behaviour.
Sensitivity and Specificity	This ABM is moderately sensitive since when inability to avoid unwanted sexual behaviour is present, female may not avoid the litter area all the time. The ABM is moderately specific because even in the absence of the welfare consequence, there could be other reasons why females avoid the litter (e.g. because resources like nests and feeding lines for the females are on the slats).

Hazards and preventive and corrective measures

Separate rearing of the sexes is a hazard, which may lead to missing male courtship behaviour when males do not get to know females (de Jong et al., 2009).

The use of dwarfed females increases the sexual size dimorphism and may invoke fear in females which will try to avoid copulations (Gebhardt-Henrich et al., 2020). The dwarfed Sasso females struggle more during copulations than the Ross females with a smaller sexual size dimorphism.

Selection for increased copulatory behaviour in the males is a risk factor for overmating. A too high ratio of males to females may also cause overmating as can *spiking*, the replacement of males by younger males during the production cycle.

The absence of a place to hide for females in systems such as floor housing without perches also lead to more struggling during copulations because females cannot escape the males (Gebhardt-Henrich et al., 2020).

A high ratio of males to females increases the frequency of mating including forced matings. Sex ratios should be optimised for high fertility and the health of female breeders. An appropriate sex ratio and degree of sexual maturity may reduce the problem. Guidelines for this are given in the handbook (Aviagen, 2018b).

A difference in sexual maturity of males and or females should be avoided, when males mature earlier than females, unwanted sexual behaviour is more likely. Similarly, if females mature earlier than males the welfare of the males might be at stake because the females would stress the males and hinder them from developing optimally (handbook Aviagen, 2018b). Females should be put first into the barn.

Even if there are perches and raised tiers, birds may vary in how often they use them.

Providing aerial perches enables females to avoid unwanted sexual behaviour from the males to a certain extent (Gebhardt-Henrich et al., 2020) and would be feasible in furnished cages. Besides perches, raised slats (van den Oever et al., 2020a), part-time separation between the sexes (van Emous, 2010), or cover panels can reduce forced copulations and overmating (Leone and Estévez, 2008).

Males should be slightly older than females when united with females while ensuring both sexes are sexually mature at this timepoint. Although reared apart, visual contact to females during rearing might be advantageous for males to get exposed to the other sex, but a positive effect of this has not been shown.

To prevent scratches and wounds of the females, spurs and the last digit of the hind toe of the males in some hybrids are cut and the beak might be trimmed (Fiks-van Niekerk and de Jong, 2007). However, these mutilations of the males are welfare-relevant on their own and can disturb mating behaviour (Jones and Prescott, 2000) and induce pain for males.

Proper management (e.g. feeding, light cycle) during rearing and production is needed to optimise the sex ratio and the timing of sexual maturity of both sexes.

3.4.2.20. Sensory under and/or over stimulation

Description of WC, category of bird and husbandry system

'Sensory under and/or overstimulation' was identified by the working group experts as a highly relevant welfare consequence for: day-old chicks hatched on hatchery and day-old chicks hatched on-farm.

Although this welfare consequence has not been retained for broiler chickens on floor systems, overstimulation may induce the ABM piling behaviour. A general definition of 'sensory under and/or overstimulation' is given in Table 5.

Sensory under and/or overstimulation occurs in day-old chicks hatched in hatcheries and on-farm. Sensory disorder occurs when the chick experiences stress and/or negative affective states such as fear or discomfort due to visual, auditory or olfactory under/overstimulation by the physical environment. Developing chicken embryos already sense photoperiodic, auditory and olfactory cues in their environment (Reed and Clark, 2011), so sensory disorder may occur both prior to hatching and after hatching. Under- as well as overstimulation should be avoided by stimulating senses according to the needs of the animals through appropriate management, environmental conditions and enrichment, the latter especially in barren environments as often applied in broiler housing.

Commonly, incubation of chicken eggs is done in darkness, and after placement on the farm chicks are housed at 23–24 h of light until they are at least 2 days old and often until they are 7 days old (Council Directive 2007/43/EC[5] allows full light up to 7 days after placement). The practice of incubating chicken eggs in darkness (24 h darkness: 24D) has been shown to have negative effects on the chicks' behaviour and welfare, possibly due to lack of both early stimulation of hemispheric lateralisation (Rogers, 2010) and early entrainment of a melatonin circadian rhythm (Zeman et al., 2004). For example, exposure to light during incubation of broiler chickens reduced fear (Archer and Mench, 2017) and resulted in use of spatial cues in addition to object-specific cues, which is likely to result in more successful food discrimination (Chiandetti et al., 2005). After placement in the barn, constant light brings overstimulation and may prevent the chickens from achieving proper rest and sleep (Schwean-Lardner et al., 2014), causing welfare problems such as stress, discomfort, fatigue and frustration. Different qualities of light should be adapted to the animal's needs, light intensity, provision of daylight, light spectrum, flicker frequency, as well as light period (Sultana et al., 2013; de Jong and Gunnink, 2019; Pan et al., 2019; Raccoursier et al., 2019; Lucena et al., 2020; Mohamed et al., 2020; Nielsen, 2020; Wichman et al., 2021; Linhoss et al., 2022). Exposure to noise during incubation has been shown to affect post-hatch behaviour and welfare. For example, exposure to experimental arrhythmic noise of 110 dB from embryonic day 10 to hatch impairs spatial learning and increases fear and stress responses (Sanyal et al., 2013). In addition to when the embryo is exposed to the sound, how often and at what pressure level, the type of sound is also important. Exposure to some sounds during incubation, like species-specific sounds or sitar music at 65 dB, may positively affect the behaviour and welfare of chicks as compared to non-stimulated control chicks (e.g. Kauser et al. (2011); Chaudhury et al. (2013); Roy et al. (2014)). Furthermore, a sound pressure level of 90 dB compared to 70 dB has been shown to result in earlier hatching, higher hatchability, better chick quality and lower weight at hatching (Donofre et al., 2020). There is limited information in the scientific literature on the quality and quantity (e.g. reflected in dB) or effect of early post-hatch exposure to sound overstimulation on the welfare of chicks. The same accounts in regard to olfaction.

Overstimulation may occur in all senses, visual, auditory, olfactory, gustatory, and somatosensory including mechanoception, thermoception and nociception. An overstimulation especially if chronic, leads to an ongoing challenge of the animal, which, in case of exceeded capabilities of adaptation, leads to a detrimental effect on welfare. An example of sensory overstimulation is the continuous light provided to day-old chicks which prevents them from proper resting (Malleau et al., 2007; Schwean-Lardner et al., 2014). The peak of sensory under- and/or overstimulation may last from prior to hatching and up until the broiler chicks are 7 days old, as the legislation allows continuous light until this age. However, it is likely more severe during the initial period after hatching, where many hatchery procedures may take place. Regardless of hatching location, the under- and/or sensory overstimulation is likely to occur, so the prevalence is rather high.

On the other hand, understimulation of broiler chickens might be present especially in two-dimensional large-scale broiler houses offering solely litter and feed/water lines as structural components. However, enriching measurements and the contribution of these have mainly be shown for broilers of 7 days of age onwards (Liu et al., 2020). The study of Güz et al. (2021) showed that intensive enrichment (perches, ramps, platforms, distance between feed and water and provision of larvae in a dustbathing area) results in not only increased active behaviour and better health status (bone quality) but also lower weight gain possibly due to higher activity levels.

Description, measurement, interpretation and characteristics of ABMs

Applicable ABMs for 'under- and/or overstimulation' are vocalisations of the animals ('distress calls' early in life), 'fear responses' (including flight reaction) in standardised tests (although these are not specific to sensorial overstimulation, see iceberg indicators in Section 3.4.2.21) as well as 'altered resting behaviour', 'piling and smothering'. The most feasible ABMs on farm are 'distress calls' and 'mortality'. The most sensitive ABM may be 'distress calls'. Farmers are often able to use vocalisations for assessment of the welfare status of the flock. There are some approaches for automatic analyses of sounds as part of Precision Poultry Farming, which are not yet validated (Li et al., 2020).

Hazards and preventive and corrective measures

The lack of a diurnal light/dark schedule during both incubation and the first days after placement in the barn (Malleau et al., 2007; Schwean-Lardner et al., 2014) is a hazard. During incubation there is a constant background noise originating from the motor and ventilation system, which has been reported to be 70 dB (Tong et al., 2015b), but it likely varies depending on the system used. Loud arrhythmic sound pressure levels have detrimental effects on chick welfare (experimental study > 110 dB) (Sanyal et al., 2013), but the threshold limit where it becomes a welfare issue is unknown. Due to the divergent results and the complexity of sound as an influencing factor on welfare, leaving many gaps of knowledge, the exact hazards related to auditory and/or olfactory stimuli during incubation remains unclear.

Sensory overstimulation can be prevented by introducing a diurnal light/dark schedule and avoiding loud arrhythmic noise during incubation seems to be beneficial to animal welfare (e.g. Sanyal et al. (2013); Archer and Mench (2017)). Knowledge on the effect of light programs and sound during the first days after hatch is limited. The practise of providing full light during the first days after hatch, which likely prevents the chickens from achieving proper rest and sleep, is meant to stimulate initiation of feeding and drinking behaviour, promoting intestinal development (Arowolo et al., 2019). To accommodate these conflicting demands regarding lighting, dark brooders or heterogeneous distribution of light intensity in the barn could be potential solutions, providing the chicks with the option of choosing between bright or darker areas.

To correct and mitigate sensory overstimulation, sudden loud noises should be stopped as soon as possible.

3.4.2.21. Iceberg indicators: ABMs related to the assessment of different WC

Some ABMs are not specific to one single welfare consequence, but they can be used to assess different welfare consequences or the general welfare status of a flock, being then considered as iceberg indicators. These ABMs are cited under the respective welfare consequences where they apply but are grouped in the section below where for each of them are indicated the animal categories, husbandry system and welfare consequences for which it applies. As these ABMs are not valid only for specific welfare consequences but for many of them, their sensitivity and specificity are not assessed here; they should rather be considered as iceberg indicators.

Iceberg indicators ABMs: 'walking impairment', 'distress calls', 'feather and body dirtiness', 'body weight loss', 'lethargy', 'mortality', 'stereotypic behaviour', 'injurious pecking' (severe feather pecking, cannibalism), 'plumage damage', 'fear response', 'piling and smothering', 'wounds', 'hock burn', 'footpad dermatitis (FPD)'.

Walking impairment

Welfare consequences – Category of bird	'Locomotory disorders' – For chickens for meat production 'Restriction of movements' – For chickens for meat production and broiler breeders
Definition	The extent to which the chicken is able to walk, varying from unaffected gait to slight changes in gait to obvious lameness or even lack of mobility (Knowles et al., 2008; Riber et al., 2021a).

Measurement	The most commonly applied method is the gait score as defined by Kestin et al. (1992). Individual broiler chickens are assigned a score between 0 and 5, varying from normal, dextrous and agile (score 0) to incapable of walking (score 5). A representative sample of chickens in a broiler house should be assessed (Welfare Quality®, 2009). Alternatively, (Webster et al., 2008) described a 3-point scoring system, with score 0 being no impairment, score 1 being obvious impairment and score 2 being severe impairment of walking ability. This 3-point scoring system correlated well with the gait score of Kestin et al. (1992). Weeks et al. (2002) developed an alternative test in which they measured the time the chickens remained standing in shallow water, which showed a good correlation with the gait score of Kestin et al. (1992). In the modified latency-to-lie test which is easier to apply in commercial houses a lying broiler is encouraged into a standing position and then the time spent standing before the broiler sat down is recorded (Bailie et al., 2013). Malchow et al. (2019b) developed the 'rotarod test' in which the time to leave a rotating rod was recorded as indicator of walking ability; an association with the gait score of Kestin et al. (1992) was found. Image analysis techniques have been developed to automatically assess flock gait score (Aydin, 2017; Silvera et al., 2017), although these are yet not widely applied in practice.
Interpretation	Studies showed no strong relationship between walking ability and leg pathologies (Riber et al., 2021a). It is yet inconclusive whether increased gait scores are associated with pain (Hothersall et al., 2016; Riber et al., 2021a; Tahamtani et al., 2021). Worse gait scores are associated with more inactivity (Riber et al., 2021a).

Distress calls

Welfare consequences – Category of bird	'Cold stress' – For day-old chicks 'Sensory under- and overstimulation' – For day-old chicks
Definition	A change in frequency (Ginovart-Panisello et al., 2020) as well as the acoustical spectrum of calls that indicate stress (Herborn et al., 2020). These include single or repeated short and loud shrieking (screaming) at high frequencies (Manteuffel et al., 2004) and distress calls in young chickens.
Measurement	Vocalisations can be recorded to assess the level of distress call or other sounds in the barn. Ideally, this should be analysed using specialised software (Herborn et al., 2020). Different parameters can be used such as the number of call bouts per time unit, the percentage of animals performing calls, or more easily the intensity of the sound level represented by decibels, frequencies and amplitude.
Interpretation	Chickens display a variety of vocalisations ranging from comfort sounds to distress calls when being stressed (Zajonc et al., 1974; Mujahid and Furuse, 2009). The very pronounced distress calls are clearly identifiable as repetitive, high-energy vocalisations made by young chickens (Herborn et al., 2020). Distress calls are highly socially facilitated. The more the distress calls, the more the welfare consequence.

Feather and body dirtiness

Welfare consequences – Category of bird	'Inability to perform comfort behaviour' – For chickens for meat production and broiler breeders 'Restriction of movement' – For chickens for meat production and broiler breeders 'Gastro-enteric disorders' – For chickens for meat production
Definition	Degree of dirtiness of the plumage and body (particularly the ventral part) due to it being wet or soiled with litter, faeces or dirt (Welfare Quality®, 2009).
Measurement	Plumage cleanliness can be scored on live chickens using the Welfare Quality® Assessment Protocol for Poultry, based on photo alignment (Welfare Quality®, 2009).
Interpretation	The integrity of the integument is of general importance for multiple welfare aspects, including thermal comfort and exhibiting successful preening behaviour. The more the feather and body dirtiness, the more the welfare consequence.

Body weight loss

Welfare consequences – Category of bird	'Prolonged thirst' – For day-old chicks 'Prolonged hunger' – For day-old chicks
Definition	A reduction in body weight in day-old chicks.
Measurement	The difference between the chicks' body weight measured using a weighing scale immediately post-hatch and upon placement.
Interpretation	The higher the body weight loss, the more severe the prolonged thirst and/or hunger. In case of 'prolonged hunger', the body weight loss is likely also partially caused by dehydration as usually neither water nor feed is provided in the hatchery (de Jong et al., 2017).

Lethargy

Welfare consequences – Category of bird	'Prolonged thirst' – For day old chicks 'Cold stress' – For day old chicks and chickens for meat production 'Heat stress' – For day old chicks and chickens for meat production 'Gastro-enteric disorders' – For chickens for meat production
Definition	Sitting motionless with head drooped or standing with eyes closed, not responding to any stimuli (Mujahid and Furuse, 2009).
Measurement	Observation of the proportion of chickens showing this behaviour in a representative sample of chickens. The specific signs of lethargy, predominantly the lack of responsiveness to any stimuli, can be observed independent of daytime.
Interpretation	Lethargy should be seen as a clinical sign of extreme discomfort and/or illness. This clinical sign should be distinguished from decreased activity as observed in fast-growing chickens at the end of the finishing period (Mujahid and Furuse, 2009). The more the lethargy, the more severe the welfare consequence.

Mortality rate

Welfare consequences – Category of bird	'Prolonged hunger' – For day old chicks 'Prolonged thirst' – For day old chicks 'Cold stress' – For day old chicks 'Handling stress' – For day old chicks 'Sensory under- and overstimulation' – For day old chicks 'Predation stress' – For chickens for meat production 'Gastro-enteric disorders' – For chicken for meat production 'Heat stress' – For all animal categories (day old chicks, chickens for meat production and broiler breeders)
Definition	Mortality rate is defined by the sum of the number of birds found dead and culled in relation to the total number of birds housed and present at the timepoint considered.
Measurement	The mortality rate is gained by dividing the total number of birds found dead in the house or culled due to health and welfare issues during the period considered by the number of birds placed, multiplied with 100 (Welfare Quality®, 2009). The period considered is typically the first week of life, the two first weeks of life or the total lifetime. These data are registered by the farmer in standard farm records.
Interpretation	The worse the welfare consequence, the higher the mortality due to it.

Stereotypic behaviour

Welfare consequences – Category of bird	'Prolonged hunger' – For broiler breeders 'Prolonged thirst' – For broiler breeders 'Inability to perform exploratory and foraging behaviour' – For broiler breeders 'Restriction of movement' – For broiler breeders 'Isolation stress' – For broiler breeders

Definition	Abnormal, repetitive, and to varying degrees fixed behaviours without an obvious goal or function ((Mellor et al., 2017)). It includes pacing and spot pecking (pecking at a specific place in the environment or on another bird). 1) Pacing: Pacing is defined as stereotyped, short-distance walking back and forth or side to side, typically manifested by animals kept in close confinement (Hurnik et al., 1985). 2) Spot pecking: The chicken pecks at inedible objects in an invariant way, e.g. at spots on the wall (called spot pecking), the empty feed trough or other structures in a stereotypic (Savory et al., 1992). This may also include stereotypic gentle feather pecking at conspecifics (Newberry et al., 2007). This stereotypic pecking at another bird is different from the severe (abnormal but not stereotypic) type of feather pecking which results in plumage damage.
Measurement	The behaviours can be observed, either directly or from videos. The repetitiveness is quite obvious even to untrained observers. It can be quantified, e.g. average repetitions per unit of time per bird (Savory and Maros, 1993). This can be expressed by occurrence of the behaviours or proportion of animals showing these behaviours (Savory and Maros, 1993).
Interpretation	This ABM is an indicator of current or previous stress and occurs, e.g. in impoverished environments where essential behaviours cannot be performed or essential resources are missing. The more the presence of stereotypic behaviour, the more severe the stress. Stereotypic behaviours indicate that the bird can suffer different welfare consequences. In summary, this behaviour always indicates stress or other negative emotions in the animal at present or in the past. The more the stereotypic behaviour displayed, the worse the welfare consequence.

Injurious pecking (severe feather pecking, cannibalism)

Welfare consequences – Category of bird	'Inability to perform exploratory and foraging behaviour' – For chickens for meat production and broiler breeders 'Prolonged hunger' – For broiler breeders 'Group stress' – For chickens for meat production and broiler breeders 'Soft tissue lesions and integument damage' – For chickens for meat production and broiler breeders
Definition	Feather pecking: The chicken pecks or pulls feathers of the flock mate causing plumage or skin damage (Nicol et al., 2013). Cannibalism: Pinching off the skin and underlying tissue of conspecifics during cannibalistic pecking leading to open wounds of the skin and in some cases even to the death of the victim. Cannibalism can represent the potential final phase of feather pecking (Blokhuis and Wiepkema, 1998). This is different from cloacal cannibalism, which is when the pecks are directed specifically at the cloaca of the victim and this form of cannibalism is not usually associated with feather pecking.
Measurement	Clinical scoring of the damage to the plumage can be according to where on the body the plumage or skin damage is observed (e.g. Bilcik and Keeling (1999)) or given as an overall score (e.g. Welfare Quality® (2009)). The ABM can also be measured by assessing the frequency of severe feather pecking. This can be expressed by occurrence of the behaviours or proportion of animals showing these behaviours (e.g. Savory and Maros (1993)). Severe feather pecks can be identified by the affected chickens vocalising and/or moving away. Clinical scoring where the number or size of wounds to the skin can be used. Again, they can be specified according to where they are on the body, e.g. around the cloaca.
Interpretation	Feather pecking is positively correlated to the inhibition of foraging and a competing motivation to exploration. Outbreaks of feather pecking are not predictable, although the inability to perform natural behaviours favours these kinds of abnormal behaviours. The pulling of feathers may cause pain, wounds and negative emotional states. The more the injurious pecking, the worse the welfare consequence.

Plumage damage

Welfare consequences – Category of bird	'Inability to perform exploratory or foraging behaviour' – For chickens for meat production and broiler breeders 'Inability to avoid unwanted sexual behaviour' – For broiler breeders 'Soft tissue lesions and integument damage' – For chickens for meat production and broiler breeders 'Group stress' – For chickens for meat production and broiler breeders
Definition	Deterioration or loss of plumage due to the action of other birds or by erosion which is caused by the rubbing with the enclosure elements, or birds. Includes damaged feathers or feather loss.
Measurement	Various protocols have been developed to assess plumage damage, although the majority has been developed for laying hens. As the protocol of Welfare Quality® (2009) also does, many require handling of individual birds. The body will be classified in different zones, e.g. head considered separately, neck, back/ rump and belly. It has also been recognised that handling birds has disadvantages in terms of bird stress, time efficiency and feasibility in large flocks. For this reason, plumage scoring methods by visual inspection of the flock that does not require individual bird handling have also been developed. Depending on the used protocol, visual scoring is supported by example pictures and calculation templates. For flock assessment, the transect method developed for poultry welfare assessment (Marchewka et al., 2013, 2015) is an efficient and sensitive method to effectively and efficiently quantify plumage damage in commercial flocks housed in alternative systems (Vasdal et al., 2022c).
Interpretation	Although plumage damage is most likely not directly painful, the action that resulted in the damage or the removal may have been (Gentle and Hunter, 1991). Also feather cover damage often leads to naked skin areas, which is a risk for skin damage and thermoregulation issues. Plumage damage increases with inability to perform exploratory and foraging behaviour (in the case of feather pecking damage) or inability to avoid unwanted sexual behaviour (de Jong and Guemene, 2011), or because of injurious pecking and aggression (Hocking and Jones, 2006). Plumage damage is also increasing with 'group stress' and is an ABM for 'soft tissue lesions and integument damages'. Although it does not lead to plumage damage, plumage condition can be worse when possibilities for dustbathing behaviour are limited because litter is wet and caked in the pen or absent. Depending on the area where the damage to the feather coverage is found a cause can be identified. Back of the head, back of the neck and the back and base of the tail are often damaged by feather pecking. The front of the neck can be damaged by the feeder, the wings and tail feathers may be damaged by system components. In breeder flocks, the feathers at the back of the head, back and thighs may be damaged due to mating behaviour of males. The more the plumage damage, the worse the welfare consequence.

Fear response

Welfare consequences – Category of bird	'Handling stress' – For day old chicks 'Sensory under- and overstimulation' – For day old chicks 'Group stress' – For chickens for meat production and broiler breeders 'Predation stress' – For chickens for meat production 'Isolation stress' – For broiler breeders
Definition	Fear responses are behavioural or physiological reactions of animals shown towards sudden, threatening and/or novel stimuli.
Measurement	From all tests probably the novel object and human approach tests are the most practical method at present for assessment of fear in commercial flocks (Welfare Quality®, 2009). The novel object test confronts the animals with an unknown object which may elicit a response of the animal ranging from curiosity and exploration to fear and avoidance (e.g. Meuser et al. (2021)). Over a given time period, the number of animals within an animal's length around the object are counted. Tests like the human avoidance test and stationary person test (Jessen et al., 2021a) involve

	the avoidance or approach, respectively, of chickens to the observer, in which case the number of birds within arm's length from the observer is recorded with fewer birds interpreted as the flocks being more fearful. Fearfulness can be measured using several non-invasive tests (Jones, 1996; Forkman et al., 2007). Some of the most used test to quantify fear in poultry are the tonic immobility test, which is a specialised restraint test (e.g. Sanotra and Weeks (2004); Anderson et al. (2021)) and the novel arena/open field test (e.g. Pelhaitre et al. (2012); Hedlund et al. (2019)). Ross et al. (2020) suggested baseline comb temperature as a chronic stress indicator in poultry. To measure fear, a startle test may also be used (Ross et al., 2020). Although this research has been with laying hens, the results are likely to be applicable to broilers or broiler breeders also. Fear tests outside the barn, e.g. in research settings, are more time consuming to collect and in the case of the startle test may not be appropriate in large groups of birds. Often, a combination of several tests is used (e.g. Giersberg et al. (2021); Meuser et al. (2021)).
Interpretation	Increased fearfulness might result in longer approach to a novel object, greater avoidance or distance to novel area or object, or attempts to move away from the test stimulus rapidly and so avoid it. Increased fear will also prolong tonic immobility; it may result in a higher basal comb temperature. The more the fear response the worse the welfare consequence.

Piling and smothering

Welfare consequences – Category of bird	'Group stress' – For chickens for meat production and broiler breeders 'Sensory under- and overstimulation' – For day old chicks
Definition	Piling can be described as a high number of chicks at a given location, resulting in unnatural density with chicks stacking on each other. Resulting from a piling event, a variable number of chicks might die due to smothering.
Measurement	Piles of birds might be found predominantly in corners. The piling itself is not a regular but an extreme event that causes losses. In this turn, the number of dead or culled birds are counted.
Interpretation	In case of piling, typically sudden and frightening events cause the flock to move to one corner resulting in a 'pile' of chicks with the ones in the corner or underneath other chicks possibly smothering to death (Gray et al., 2020). The causing factors and their intensity, e.g. how loud a sudden noise was, is not directly correlated to the severity of the piling event. The general fear or stress level of the flock as well as the context in which the chicken has experienced an unpredicted event might contribute to the extent of the flight response. The more the piling and smothering the worse the welfare consequence.

Wounds

Welfare consequences – Category of bird	'Soft tissue lesions and integument damage' – For chickens for meat production and broiler breeders 'Restriction of movement' – For chickens for meat production and broiler breeders 'Inability to avoid unwanted sexual behaviour' – For broiler breeders
Definition	Wounds comprise all lesions to the skin (skin lesion being an injury that has not yet completely healed), ranging from minor superficial punctiform spots to scratches to large open wounds that go deeper than the skin (Welfare Quality Network, 2019). It also includes Injuries/Wounds/Scratching/Wounds at the back of the neck and head, and on the back of the body of breeding females. Mutilations to breeding birds such removal of claws or spurs in breeding males or beak trimming are also wounds.
Measurement	Wounds may be difficult to score from a distance as they can be covered with feathers and especially small scratches or lesions might be difficult to detect, so manual scoring of a representative number of individuals should be preferred. Wounds and scratches can be scored according to a three-point or four-point classification scale: (1) 3-point scoring system with 0 = no lesions or single pecks or scratches (< 3) pecks punctiform damage < 0.5 cm diameter); 1 = at least one lesion > 0.5 cm but smaller than 2 cm diameter or ≥ pecks or

	scratches and 2 = at least one lesion ≥ 2 cm diameter (Welfare Quality Network, 2019); (2) 4-point scoring system with score 0 = no scratches visible, 1 = small, superficial scratch or scratches; 2 = deep scratch penetrating the skin or wound (< 1.5 cm length or diameter); 3 = large scratch or wound (> 1.5 cm length or diameter) (de Jong et al., 2014). More simply scoring is also used, such a simple yes/no score (absence vs presence of scratches or wounds (Tahamtani et al., 2020). Alternatively, broilers can be scored from a distance of 1–2 m using the transect walk method where all birds having tail, back and head wounds are scored (wounds visible by fresh or dried blood or scabs) (BenSassi et al., 2019a), by this method likely only broilers with large wounds will be scored. Mutilations to the feet are easily seen from a distance or 1–2 m. The ease with which it can be determined whether the birds have been beak trimmed depends on how much of the beak has been removed.
Interpretation	The more wounds (severity and prevalence), the bigger the impairment of the welfare.

Hock burn

Welfare consequences – Category of bird	‘Soft tissue lesions and integument damage’ – For chickens for meat production and broiler breeders ‘Restriction of movement’ – For chickens for meat production and broiler breeders
Definition	Hock burns are a type of contact dermatitis (see definition under ‘footpad dermatitis’, ‘restriction of movement’) affecting the caudal part of the hock joint (Sherlock et al., 2010). The skin is acutely inflamed. This health problem causes pain and may cause lameness and with less locomotion and lower feed and water intake.
Measurement	Hock burn is assessed by a visual scale (e.g. Welfare Quality Protocol, (Welfare Quality®, 2009)). A score of 0 represents no dermatitis, 1–2 mild dermatitis, and 3–4 severe dermatitis.
Interpretation	Especially poor litter quality is a hazard for the development of hock burns. Lameness or decreased activity aggravate to the prevalence as the birds are sitting more on the litter. The more hock burns (severity, prevalence), the higher the welfare impairment.

Footpad dermatitis

Welfare consequences – Category of bird	‘Soft tissue lesions and integument damage’ – For chickens for meat production and broiler breeders ‘Restriction of movement’ – For chickens for meat production and broiler breeders ‘Gastro-enteric disorders’ – For chickens for meat production
Definition	Footpad dermatitis is a type of contact dermatitis affecting the foot and toe pads. Contact dermatitis are inflammatory states in the subcutaneous tissue leading to hyperkeratosis, necrosis and ulcerations (Weitzenburger et al., 2006; Roenchen et al., 2007).
Measurement	In most cases, a three-point, four-point or five-point scoring system is used to describe the macroscopic findings when the underside of the foot is inspected, and the area and type of damage compared to a standardised series of photographs. In some cases, scores can also be later combined. For example, in the Welfare Quality® Assessment Protocol for Poultry, the five initial levels are combined as ‘a’ – no evidence of footpad dermatitis (score 0), ‘b’ – minimal evidence of footpad dermatitis (scores 1 and 2), or ‘c’ – evidence of footpad dermatitis (Welfare Quality®, 2009). A large enough sample of birds should be examined, e.g. 100 birds per flock. If scored on the farm, they should be selected from different areas of the building and if scored at the slaughterhouse from different parts of the slaughter-line. The scoring at the slaughterhouse has opened the possibility for automated systems to assess the extent of the dermatitis (Vanderhasselt et al., 2013; Kaewtapee et al., 2021). Automated systems mean that more birds can be assessed per flock and reliability of scoring is higher.

Interpretation	Histological studies have found that macroscopic scoring of footpad dermatitis mirrors histological findings (Piller et al., 2020). These inflammatory and necrotic lesions are most certainly painful. They have also been found to be associated with the presence of pathogens (Alpigiani et al., 2017). Thus, the more footpad dermatitis that is observed (the higher the score and the higher the number of individuals in the flock affected), the higher the welfare consequences.

3.4.2.22. Link between ABM, welfare consequences and category of bird

Table 7 summarises the highly relevant welfare consequences for the three concerned category of birds and husbandry systems as well as the recommended ABMs

Table 7: Link between welfare consequences, ABMs, and category of birds

WC	ABM	Category of birds		
		Day-old chicks	Chickens for meat production	Broiler breeders
Bone lesions	**Keel bone fracture**			X
Cold stress	**Huddling**	X	X	
	Cloacal temperature	X	X	
	Surface temperature	X		
	Lethargy *(iceberg indicator)*	X	X	
	Mortality *(iceberg indicator)*	X		
	Distress calls *(iceberg indicator)*	X		
Inability to perform comfort behaviour	**Dustbathing**		X	X
	Preening		X	X
	Wing and leg stretching		X	X
	Wing flapping		X	X
	Feather and body dirtiness *(iceberg indicator)*		X	X
Inability to perform exploratory or foraging behaviour	**Walking, scratching and pecking as part of foraging or exploratory behaviour**		X	X
	Injurious pecking *(iceberg indicator)*		X	X
	Plumage damage *(iceberg indicator)*		X	X
	Stereotypic pacing behaviour *(iceberg indicator)*			X
Gastro-enteric disorders & other infectious diseases	**Feather and body dirtiness** *(iceberg indicator)*		X	
	Footpad dermatitis *(iceberg indicator)*		X	
	Cloacal temperature		X	
	Lethargy *(iceberg indicator)*		X	
	Impaired growth rate		X	
	Mortality *(iceberg indicator)*		X	
Prolonged hunger	**Body weight loss** *(iceberg indicator)*	X		
	Impaired growth rate			X
	Polydipsia			X
	Stereotypic behaviour *(iceberg indicator)*			X
	Mortality *(iceberg indicator)*	X		
	Injurious pecking *(iceberg indicator)*			X
Prolonged thirst	**Mortality** *(iceberg indicator)*	X		
	Body weight loss *(iceberg indicator)*	X		
	Lethargy *(iceberg indicator)*	X		

WC	ABM	Category of birds		
		Day-old chicks	Chickens for meat production	Broiler breeders
	Pinch test			X
	Voluntary water test consumption			X
	Stereotypic behaviour *(iceberg indicator)*			X
Heat stress	**Panting**		X	
	Lethargy *(iceberg indicator)*		X	
	Wings are held away from the body		X	
Handling stress	**Chick righting time**	X		
	Orientation and posture on the conveyor belts	X		
	Chicks falling on the floor	X		
	Fear response *(iceberg indicator)*	X		
	Mortality *(iceberg indicator)*	X		
	Escape attempts			X
	Resistance to handling			X
Isolation stress	**Stereotypic Behaviour** *(iceberg indicator)*			X
	Fear response *(iceberg indicator)*			X
Locomotory disorders	**Walking impairment** *(iceberg indicator)*		X	
	Leg deformation		X	
	Flock activity		X	
Predation stress	**Mortality due to predation**		X	
	Fear response *(iceberg indicator)*		X	
Restriction of movement	**Locomotory behaviour**		X	X
	Feather and body dirtiness *(iceberg indicator)*		X	X
	Wing flapping		X	X
	Footpad dermatitis *(iceberg indicator)*		X	X
	Hock burn *(iceberg indicator)*		X	X
	Wounds *(iceberg indicator)*		X	X
	Walking impairment *(iceberg indicator)*		X	X
	Stereotypic behaviour *(iceberg indicator)*			X
Resting problem	**Resting birds**	X	X	X
	Bird disturbance	X	X	X
Group stress	**Fear response** *(iceberg indicator)*		X	X
	Plumage damage *(iceberg indicator)*		X	X
	Aggressive interaction		X	X
	Piling and smothering		X	X
	Injurious pecking *(iceberg indicator)*		X	X
Soft tissue lesions and integument damage	**Wounds** *(iceberg indicator)*		X	X
	Breast blisters		X	X
	Breast burn		X	X
	Bruises		X	X
	Cellulitis		X	X
	Footpad dermatitis *(iceberg indicator)*		X	X
	Plumage damage *(iceberg indicator)*		X	X

WC	ABM	Category of birds		
		Day-old chicks	Chickens for meat production	Broiler breeders
	Hock burn *(iceberg indicator)*		X	X
	Injurious pecking *(iceberg indicator)*		X	X
Umbilical disorders	**Navel condition**	X		
Inability to avoid unwanted sexual behaviour	**Forced copulations**			X
	Avoidance of the litter area by the females			X
	Wounds *(iceberg indicator)*			X
	Plumage damage *(iceberg indicator)*			X
Sensorial under and overstimulation	**Fear response** *(iceberg indicator)*	X		
	Resting behaviour	X		
	Distress calls *(iceberg indicator)*	X		
	Mortality *(iceberg indicator)*	X		
	Piling and smothering	X		

3.5. Enclosure requirements in broiler production (broiler breeders, broiler chickens (fast- and slower-growing))

Section 3.4.2 clearly describes that many welfare consequences have common hazards (e.g. low space allowance, poor litter quality). This section describes these hazards (exposure variables) and provides recommendations about the characteristics of the minimal enclosure that would prevent broilers from experiencing negative welfare consequences. These recommendations will be done for each identified hazard (e.g. space allowance, litter, perches, light, temperature, etc.) and key parameters (e.g. minimal space per bird) that will be specified to define the minimal enclosure. The recommendation for each key parameters are valid considering that all other parameters are also following the recommendations specified in the minimal enclosure section, meaning 'all other parameters being optimal'.

As described in general ToRs and summarised in different recommendations, cages such as described in Sections 3.3.8 and 3.3.9 of this Scientific Opinion should not be used to avoid many welfare consequences in broiler breeders.

Based on animal welfare considerations, key parameters and their specifications are defined here for the minimal enclosure that would prevent the birds from experiencing highly relevant welfare consequences, i.e. 'inability to perform exploratory behaviour and foraging', 'inability to perform comfort behaviour', 'restriction of movement', 'soft tissue lesions and integument damage'. This section focuses on fast-growing broiler chickens, but when breeders or slower-growing broilers have different specific needs compared to the ones of the fast-growing broilers, it will be indicated.

The key parameters recommendation can be separated in two groups: the equipment and the management characteristics.

They will be described in Sections 3.5.1 and 3.5.2, with their respective conclusions and recommendations described in Section 4.2.1.

Table 8 shows the link between the list of hazards and the highly relevant welfare consequences.

Table 8: List of identified hazards and their relationship with the 19 identified highly relevant welfare consequences in broilers. Hazards are clustered related to health and breeding, management and equipment respectively. The last column summarises for each hazard the total number welfare consequences that are affected by these hazards as well as the proportion (%) in relation to total number of welfare consequences considered

Hazards/welfare consequences	Bone lesions	Cold stress	Inability to perform comfort behaviour	Inability to perform exploratory or foraging behaviour	Gastro-enteric disorders	Prolonged hunger	Prolonged thirst	Heat stress	Handling stress	Isolation stress	Locomotor disorders	Predation stress	Restriction of movement	Resting problems	Group stress	Soft tissue lesions and integument damage	Umbilical disorders	Inability to avoid unwanted sexual behaviour	Sensorial under and over-stimulation	TOTAL of Welfare Consequences (%) affected by the hazard
Hazards linked to health and breeding																				
Genetics	x			x	x	x					x	x	x		x	x		x		10 (52.6%)
High growth rate											x		x			x				3 (15.8%)
Impaired locomotor health				x							x		x			x				4 (21.1%)
Hazards linked to the management																				
Single housing										x										1 (5.3%)
Size of the cage			x	x									x			x				4 (21.1%)
Space allowance			x	x	x			x			x		x	x	x	x				9 (47.4%)
Rough mating																x				1 (5.3%)
Male and female ratio															x			x		2 (10.5%)
Spiking																		x		1 (5.3%)
Separate rearing of sexes																		x		1 (5.3%)
Different sexual maturity age males and females															x			x		2 (10.5%)
Bad light management			x	x							x			x					x	5 (26.3%)

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Hazards/welfare consequences	Bone lesions	Cold stress	Inability to perform comfort behaviour	Inability to perform exploratory or foraging behaviour	Gastro-enteric disorders	Prolonged hunger	Prolonged thirst	Heat stress	Handling stress	Isolation stress	Locomotor disorders	Predation stress	Restriction of movement	Resting problems	Group stress	Soft tissue lesions and integument damage	Umbilical disorders	Inability to avoid unwanted sexual behaviour	Sensorial under and over-stimulation	TOTAL of Welfare Consequences (%) affected by the hazard
Too low effective temperature		x																		1 (5.3%)
Too high effective temperature					x		x	x								x	x			5 (26.3%)
High humidity								x			x									2 (10.5%)
Poor ventilation		x					x	x			x									4 (21.1%)
Insulation		x						x												2 (10.5%)
Feed deprivation/ restriction						x														1 (5.3%)
Lack of biosecurity measures					x															1 (5.3%)
Staff under time pressure									x											1 (5.3%)
Absence or poor-quality litter			x	x	x						x		x			x				6 (31.6%)
Poorly trained staff					x				x								x			3 (15.8%)
Noise														x					x	2 (10.5%)
Water deprivation						x	x													2 (10.5%)
Inappropriate feed content	x				x		x				x									4 (21.1%)
Hazards linked to the equipment																				
Inappropriate perches	x		x											x						3 (15.8%)

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Hazards/welfare consequences	Bone lesions	Cold stress	Inability to perform comfort behaviour	Inability to perform exploratory or foraging behaviour	Gastro-enteric disorders	Prolonged hunger	Prolonged thirst	Heat stress	Handling stress	Isolation stress	Locomotor disorders	Predation stress	Restriction of movement	Resting problems	Group stress	Soft tissue lesions and integument damage	Umbilical disorders	Inability to avoid unwanted sexual behaviour	Sensorial under and over-stimulation	TOTAL of Welfare Consequences (%) affected by the hazard
Barren environment			X	X							X		X							4 (21.1%)
Lack of elevated structures (perches and platforms)			X									X	X	X		X				5 (26.3%)
Technical problems with conveyor belts									X					X						2 (10.5%)
Underdimensioned resources														X	X	X				3 (15.8%)
Wired floor				X												X				2 (10.5%)
Unfurnished outdoor range															X					1 (5.3%)
Change of type or space of drinkers							X													1 (5.3%)
Furnishing with sharp edges																X				1 (5.3%)
Lack of shelters								X				X								2 (10.5%)
Inappropriate fences												X								1 (5.3%)

3.5.1. Management

3.5.1.1. Space allowance (Specific ToR 1c)

In this section the results of the two methods: the EKEs and behavioural space model were used to address this specific ToR 1c regarding the space needed per bird are presented.

Welfare consequences experienced by broilers kept in barns with limited space allowance include 'restriction of movement' (Buijs et al., 2010), 'resting problems' (Buijs et al., 2010; Ventura et al., 2012), 'inability to perform comfort behaviour' (Buijs et al., 2010; Knierim, 2013), 'inability to perform exploratory and foraging behaviour' (Ventura et al., 2012; Knierim, 2013), 'soft tissue lesions and integument damage' (Ventura et al., 2010; Knierim, 2013; Mocz et al., 2022) and 'locomotory disorders' (Buijs et al., 2009; Knierim, 2013; Tahamtani et al., 2020).

Expert Knowledge Elicitations (EKEs)

ABMs to assess the effect of space allowance on the welfare of fast-growing chickens

'Footpad dermatitis (FPD)' was chosen as an ABM which is directly linked with the space allowance via its relation to litter quality (Kaukonen et al., 2017a) and the fact that it is frequently measured and available in many studies. It was chosen as an ABM for the 'soft tissue lesion and integument damage'. The prevalence of FPD is of high relevance for the welfare of the broilers and there were enough quantitative data available in literature to run an EKE.

In order to choose a second ABM for the EKE, an ABM was selected which is associated with a biological functioning of the animal and which has relevance for positive animal welfare, e.g. the ability of the animal to explore the environment, be active and get access to resources in the barn (Lawrence et al., 2019). Therefore, **'% time walking'** was chosen as an ABM for the welfare consequence 'inability to perform exploratory and foraging behaviour' and restriction of space. This ABM is used complementary to FPD to measure the effect of the space allowance on the welfare of broilers. Walking is one of the behaviours most affected by space allowance.

Two EKEs integrating the general concept of a 'non-exposed' population and based on expert estimates were applied (see Appendix B for more details). In both EKEs, evidence from experimental studies published in peer-reviewed journals served as a basis to estimate the relationship between the two variables (1) % time walking and (2) FPD with the stocking density.

'Non-exposed' population

For the purposes of the two EKEs, the 'non-exposed' population was defined as a hypothetical group of broiler chickens of a 'fast-growing' hybrid, 5 days before slaughter, housed in a barn with concrete flooring with wood shavings and good ventilation, where good management practices are applied (no leaking water, normal daily care), and with an environmental temperature of around 20°C and 17 h of light, with a stocking density of 3 kg/m^2 or below (i.e. a space allowance of 1 bird/m^2).

'Highly exposed' population

For the purposes of the EKEs, the 'highly exposed' population was defined as a hypothetical group of broiler chickens of a 'fast-growing' hybrid 5 days before slaughter, housed in a barn with concrete flooring with wood shavings and good ventilation, where good management practices are applied (no leaking water, normal daily care), and with an environmental temperature of around 20°C and 17 h of light, with a stocking density of about 35 kg/m^2.

EKE 1 scope and assumptions

The first EKE exercise aimed at estimating the effect of increasing amounts of stocking density (measured in 'kg/m^2 available to the broiler chickens') on 'the proportion of time during the light period that an average bird is walking'. For this EKE, walking is described as a slow forward movement, breast above the floor, using legs without performing any other activity (Ipema et al., 2020; Abeyesinghe et al., 2021). This does not include other types of locomotion such as running, wing-assisted running or play fighting (Dawson et al., 2021).

For this first EKE, the behaviour expected in the non-exposed population of broiler chickens acted as an anchor point to estimate the proportion of time walking expected in broilers with no restriction of space.

EKE 2 scope and assumptions

The second EKE aimed at estimating the effect of increasing amounts of stocking density (measured in 'kg/m^2 available to the broiler chickens') on the FPD score. FPD is measured by applying a three-point (see Table 9), four-point or five-point scoring system used to describe the macroscopic findings when the underside of the foot and the area and type of damage are compared to a standardised series of photographs. The three-point scoring system is most frequently used both in literature as well as by, e.g. slaughter plants for welfare evaluation (de Jong et al., 2012b; Kyvsgaard et al., 2013). When necessary, the four- and five-point scoring systems can be translated into the three-point scoring system, as these are a more detailed way of scoring FPD, usually based on the size and severity of the lesion. The three-point scale is defined as indicated in Equation 5.

For the second EKE, the FPD score in the non-exposed population of broiler chickens acted as an anchor point to estimate the FPD score in broilers with no restriction of space and assumed to be 0 (zero).

$$\text{Average FPD score} = 0 * P0 + 1 * P1 + 2 * P2 \qquad (5)$$

Table 9: Three-level scoring system to score footpad dermatitis

Score (3-level)	Short description	Remarks	Proportion within the flock
0	No lesions	No evidence of footpad dermatitis	P0
1	Mild lesions	Minimal evidence of footpad dermatitis	P1
2	Severe lesions	(Clear) evidence of footpad dermatitis	P2

For both EKEs it was assumed that unrestricted access corresponded to stocking density of 3 kg/m^2 (space allowance of 1 bird/m^2).

Main data gaps on FPD score and the proportion of time walking by birds:

Although there were sufficient data for FPD and % time walking under intermediate and high densities, there was a lack of data on FPD scores and the % time walking under low stocking densities. In addition, FPD is a multifactorial problem. A high variation in the FPD scores was observed, likely due to other factors than or in addition to stocking density. Those factors affecting FPD were not identified in the study, as indicated in Appendix B.

Results

<u>Results from EKE 1-% time walking</u>

The results of the first EKE are presented in Figure 15.

It was estimated that – under unrestricted access to space – the 'average' fast-growing broiler chicken within 5 days of slaughter is expected to walk **8.5% of the light period (17 h)** (90% credible intervals 2.4–20%).

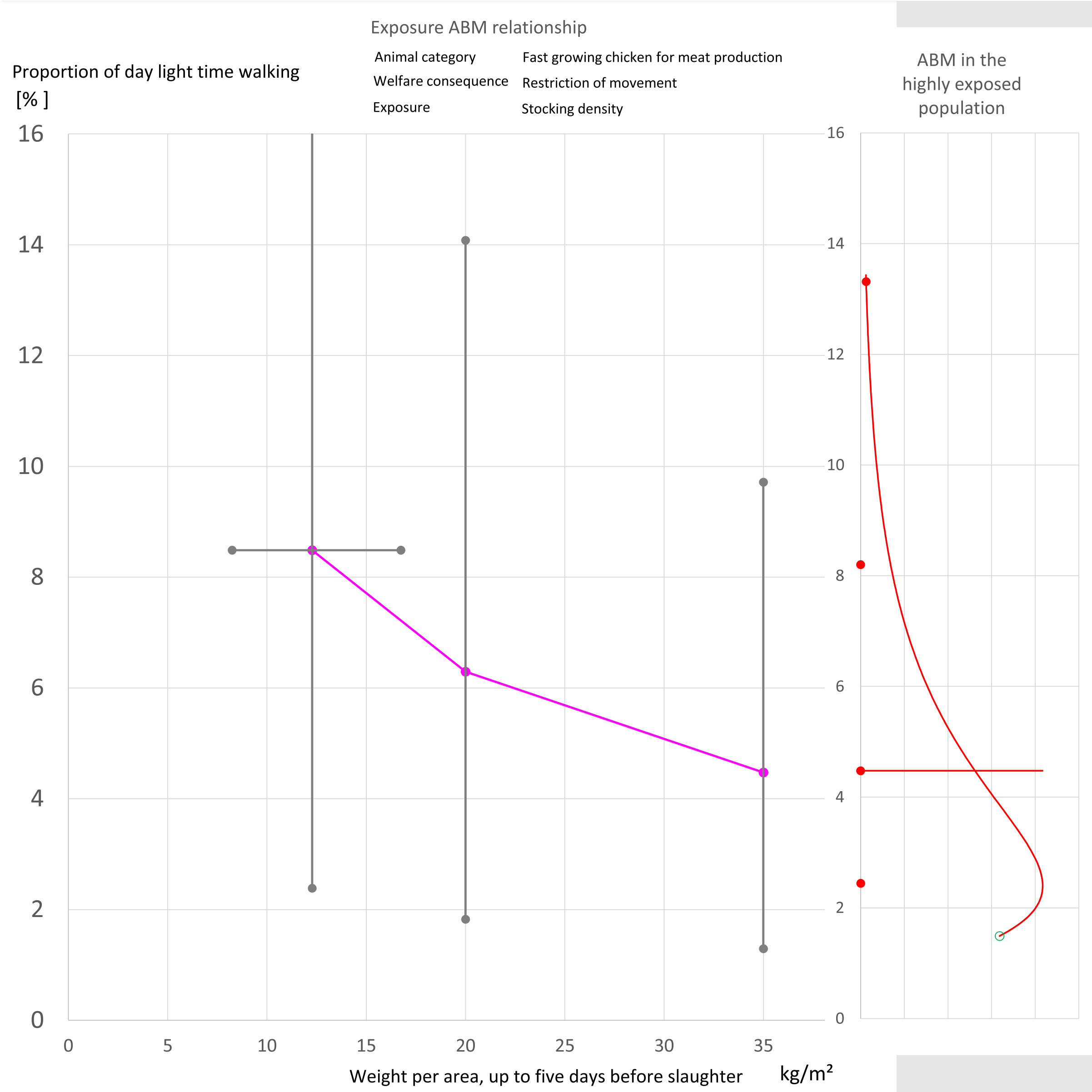
It was estimated that a **stocking density of 12 kg/m^2 (90% credibility interval from 8 kg/m^2 to 17 kg/m^2)** would allow an average broiler chicken to express/have the same level of % walking as shown by the 'median' animal under unrestricted conditions. Thus, at a space allowance of 12 kg/m^2, walking behaviour was estimated to be 8.5% for the 'median' fast-growing broiler within 5 days before slaughter (Table 10). This corresponds with 93% increase of time walking as compared with the highly exposed population (at a stocking density of 35 kg/m^2).

In order to perform further interpolations, the variation was assessed under unrestricted conditions and restricted conditions. No data were available to describe the variation between chicken with unrestricted access to space. Instead, it was estimated that under highly restricted conditions (high stocking densities) the same level of % walking ($\pm$ 8.2% or more) would be expressed by only 10% of the broilers (10th percentile of the population).

The working group experts were requested to estimate the % of walking for two different ranges of stocking densities: one between high density (35 kg/m^2) and intermediate density (20 kg/m^2) and one between 20 kg/m^2 and the density of the non-exposed population. For that reason, two linear interpolations could be evaluated and it was shown that the overall linear interpolation could be applied. Between 35 and 20 kg/m^2 there was an increase of 0.11% of walking per decreased kg/m^2

(90% credible interval 0.03%-0.34%). Between 20 and 12 kg/m^2 there was an increase of 0.25% walking per decreased kg/m^2 (90% credible interval -0.07% to 1.32%) (see Figure 15 pink line).

Overall, decreasing the stocking density from 35 kg/m^2 to 12 kg/m^2 resulted in an 93% increase of time spent walking (credible interval 42–147%). At a high stocking density (35 kg/m^2), the expected average proportion of time spent walking is 4.48% of the light period (17 h) with 90% credible interval 1.3–9.7%.



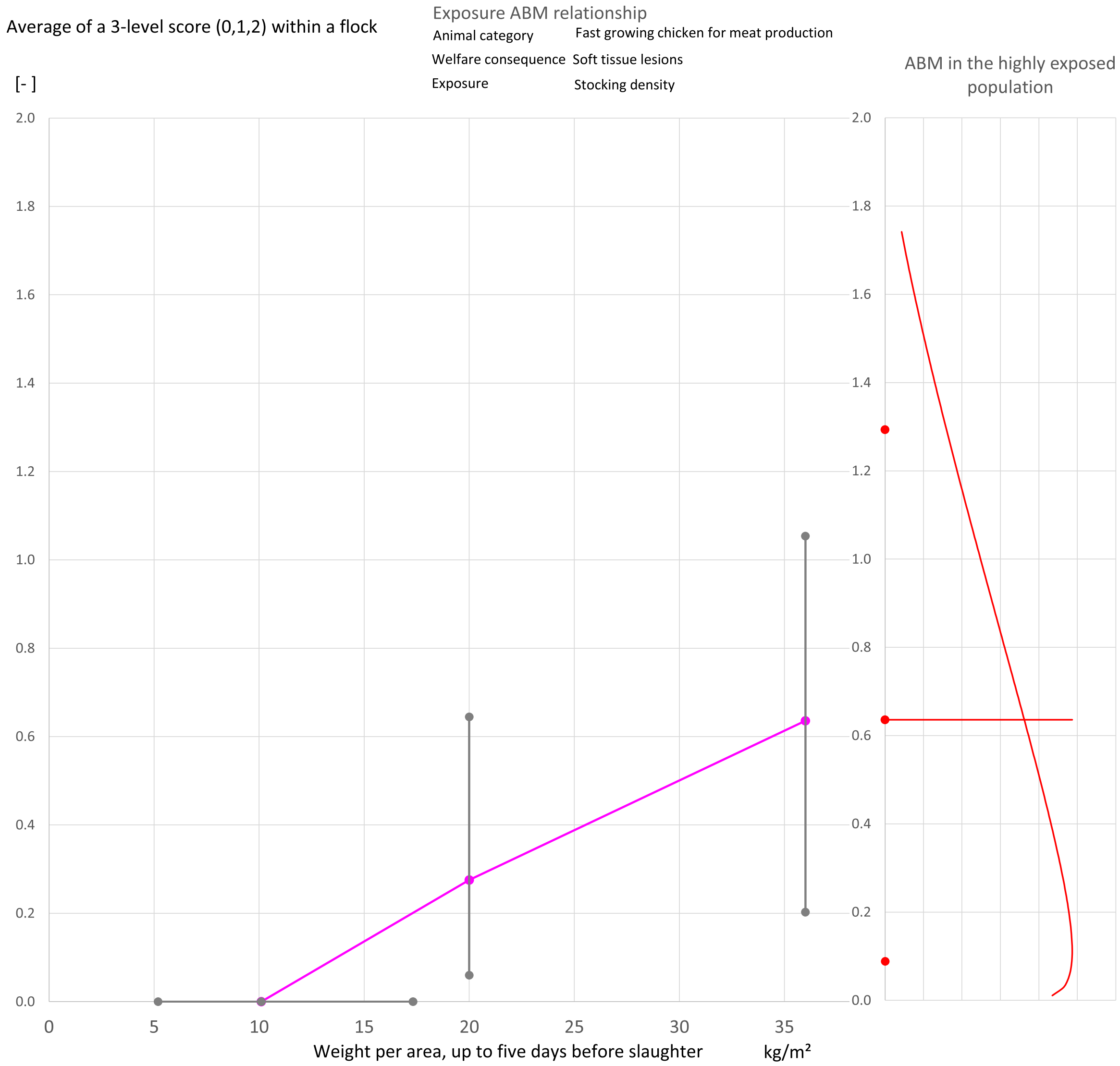
Four values (shown in pink with grey certainty ranges) were obtained by EKE. A linear relationship between increasing space allowances (kg/m^2) and % time walking is assumed (pink line) to interpolate the EKE results. The red distribution on the right-hand side of the plot represents the variability in % time walking expected in a population of broilers placed in a barn with highly restricted space (e.g. minimal allowed space or high stocking densities). No data were available to describe the variability in % time walking expected in a population of broilers placed in a barn with unrestricted access to space (low stocking density).

Figure 15: Stepwise linear relationship (pink line) between the stocking density (x-axis) and % of time walking during day time (y-axis)

Results from EKE 2 – FPD score

It was estimated that under unrestricted access to space the 'average' fast-growing broiler chicken within 5 days prior to slaughter is expected to have an average FPD score of zero (95% credibility intervals 0–0.04).

It was estimated that a **stocking density of 10 kg/m^2** (90% credibility interval 5.2, 17.3) would allow fast-growing broiler chicken within 5 days of slaughter to express/have the same level FPD score as shown by the 'median' animal under unrestricted conditions (FPD score 0), see Figure 16.



Three values (shown in pink with grey certainty ranges) were obtained by EKE. A stepwise linear relationship between increasing space allowances (kg/m^2) and average FPD score is assumed (pink line) to interpolate the EKE results. The red, vertical distribution on the right-hand side of the plot represents the variability in the average FPD score expected in a population of broilers placed in a barn with highly restricted space (e.g. minimal allowed space).

Figure 16: Stepwise linear relationship (pink line) between the stocking density (x-axis) and the ABM, here the average FPD score

Summary of the EKE on the impact of stocking density on FPD and % time walking

Table 10: Relationships between stocking density (kg/m^2) and (1) average and reduction in FPD scores at the flock level and (2) % time and increase in % time spent walking based on the EKE estimates for the 'average' broiler and assuming a linear relationship between time spent walking, the FPD score and stocking densities

Stocking density (kg/m^2)	Median FPD scores (from 0 to 2) and (90% credible intervals in squared brackets) FPD score (min=0, max=2) (linear model)	Median Reduction (%) of FPD scores relative to the highest stocking density 90% credible intervals in squared brackets (linear model)	Median (%) of time spent walking and 90% credible interval in squared brackets (linear model)	Median increase (%) of time spent walking relative to the difference between average broilers with high[(a)] and no restriction[(b)] in space (90% credible interval in squared brackets) (linear model)
35–36	0.64 [0.20, 1.05]	0%	4.5 % [1.29, 9.72]	0%
30	0.48 [0.21, 0.81]	25% [0, 67]	5.2 % [1.5, 11.1]	16% [7, 25]
25	0.38 [0.17, 0.68])	41% [0, 74]	5.2% [1.5, 11.1]	28% [14, 50]
20	0.28 [0.06, 0.64]	57% [0, 91]	6.3% [1.8, 14.1]	21% [20, 75]
15	0.15 [0, 0.36]	77% [44, 100]	7.8% [2.3, 18.4]	74% [39, 154]
12	0.06 [0, 0.22]	91% [65, 100]	8.5% [2.4, 19.7]	90% [42, 147]
10	0.01 [0–0.22]	98% [65, 100]	9.1% [2.5, 24.4]	103% [41, 269]
3–7	0 [0–0.04]	100% [93, 100]	9.8% [2.6, 28]	120% [39, 337]

Values above 100% indicate the uncertainty of the linear model. Orange cells indicate values elicited by the experts in the two expert knowledge elicitation exercises conducted. (a): Highly exposed (35–36 kg/m^2) set to 0% increase of walking behaviour. (b): Unexposed (10.1 kg/m^2) set to 100% increase of walking behaviour.

Results from the behavioural model used to estimate the stocking density of broiler chickens

In total, 17 studies published after 2010 were chosen for data extraction of % of the behaviour. These references resulted in 81 data points (N, specific values for a given behaviour), ranging from 4 data points for wing flapping to 12 data points for drinking/eating and sitting/resting. On average, 9 data points were extracted per behaviour (see Appendix C for detailed results).

Table 11 shows the behaviours that are considered essential for 'improved' welfare. Behaviours considered as needs for broiler chickens were selected and data extracted on the proportion of broilers performing these behaviours data within a flock of broilers under optimal conditions using mean, median, optimum and stabilized optimum of the extracted data (Table 11) and space required (including the interindividual distance) to perform them (Table 12). Details are described in Section 2.3.2.1.

Table 11: Selected behaviours and their label and the proportion of broilers performing these behaviours within a flock of broilers under optimal conditions for the median, mean, optimal and stabilised optimal scenario (The behaviours have been standardised to 100 % in each approach of the model)

Behaviour	Label	Median	Mean	Optimum	Stabelised optimum
		%	%	%	%
Standing	Stationary	9.3%	9.5%	4.9%	5.8%
Sitting	Stationary	51.6%	45.0%	27.0%	31.9%
Walking	active	3.4%	4.6%	6.9%	7.4%
Foraging incl. Scratching	active	3.8%	5.1%	9.0%	8.7%
Dustbathing	active	2.5%	4.8%	7.1%	8.0%
Preening	active	5.5%	7.1%	19.4%	13.7%
Wing/leg stretching	active	2.9%	4.8%	11.5%	8.4%
Wing flapping	active	6.4%	6.0%	6.6%	7.1%
Drinking/Eating	Stationary	14.5%	13.0%	7.6%	9.0%
Sum		**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table 12: Nine selected behaviours and the space required to perform them including the interindividual distance and the total area required to perform them

Behaviour	Label	Space (cm^2)	Interindividual distance (D) (cm)	Area A (cm^2)
Standing	Stationary	473.20	22.3	1900.5
Sitting/Resting	Stationary	496.75	23.3	2032.8
Walking	active	946.4	22.9	2874.6
Foraging	active	808.10	23.3	2463.9
Dustbathing	active	1036.50	24.3	2895.1
Preening	active	1085.60	25.3	2969.6
Wing/Leg stretching	active	843.00	26.3	2879.5
Wing flapping	active	2254.20	27.3	5664.2
Drinking/Eating	Stationary	476.90	24.4	2260.8

The results (Table 13) show that the stocking density ranges between 10.06 and 11.28 kg/m^2 corresponding to 3.67–4.12 broilers/m^2.

Table 13: Space allowance (cm^2/broiler chicken) estimated for the median, mean, optimal and stabilised optimal model. The number of chickens per m^2 and the stocking density in kg/m^2 is also provided

Behaviour	Space allowance (cm^2/broiler chicken)			
	Median cm^2	Mean cm^2	Optimal cm^2	Stabilised optimal cm^2
Standing	177.5	181.4	92.8	109.7
Sitting/Resting	1049.3	915.4	548.5	648.6
Walking	97.5	132.4	197.4	211.8
Foraging	94.3	124.9	222.0	214.1
Dustbathing	72.2	139.6	205.9	232.3
Preening	163.8	211.4	575.5	407.8
Wing/Leg stretching	83.6	137.7	332.4	243.0
Wing flapping	362.4	338.6	376.0	401.9
Drinking/Eating	328.1	295.0	171.5	202.8
Total area per chicken (cm^2)	2428.7	2476.4	2721.9	2672.1
No. chicken per m^2	**4.12**	**4.04**	**3.67**	**3.74**
kg per/m^2	**11.28**	**11.06**	**10.06**	**10.25**

Table 13 shows the results of the behavioural model (Section 2.3.2.1 methodology) – expressed as maximum number of broilers/m^2 and maximum stocking density (kg/m^2) at any time – for the following outcomes of the model: median, mean, optimal and stabilised optimal model.

Sensitivity analysis of the behavioural model on space allowance

The uncertainty related to the behavioural space allowance is mainly caused by the differences in the study results on the % time spent wing flapping, space requirements for sitting, % time sitting and the interindividual distance of sitting (Table 14).

Table 14: Results of the uncertainty analysis of the inputs of the behavioural model on space allowance (listed are the 12 input parameters (in terms of % of animals or space covered) with highest influence on the overall uncertainty, contributing together more than 95%)

Model input	Contribution to the total uncertainty [Coefficient of determination R^2- %]
Behaviour Flapping	34%
Space Sitting	17%
Behaviour Sitting	15%
Interindividual Distance Sitting	9%
Behaviour Preening	7%
Space Standing	4%
Behaviour Standing	3%
Space Preening	2%
Behaviour Stretching	2%
Interindividual distance Eating	1%
Interindividual distance Preening	1%
Behaviour Dustbathing	1%
Others	5%

[% R^2] = relative contributions of each input parameter to the total uncertainty (expressed as the proportion of variance by R^2 (coefficient of determination) of the multiple regression model connecting the model output with the input parameters).

Combination of the results of the EKE and behavioural model approach

The median of the stocking density was used for both the EKEs results and the behavioural model results, because it is a more robust descriptive statistic than the average~~.~~

The maximal stocking above which FPD score will increase, walking ability will be reduced and behavioural needs realisation is impaired because of lack of space is 11 kg/m^2.

3.5.1.2. Minimal height at any point

It seems obvious to suggest that the minimum height in a housing system should never be less than the height of the bird itself. There is no available accurate measurement for the height of broilers or broiler breeders when performing different activities. However, measurements on laying hens have shown that the average height for a laying hen that is standing is 34.8 $\pm$ 1.3 cm and this increases to 38.6 $\pm$ 2.3 cm for turning (Mench and Blatchford, 2014). The behaviour that requires most height to perform is wing flapping. Research on laying hens reported that a bird wing flapping is 49.5 $\pm$ cm high (Mench and Blatchford, 2014), i.e. approximately 15 cm greater than the height of the standing bird.

In a paper discussing the height of cages for transporting broilers to slaughter, it was proposed that the height of a standing commercial broiler is 35–40 cm (Vinco et al., 2016). Based on a standing height of 40 cm (i.e. approximately 5 cm taller than the layers used by Mench and Blatchford (2014) and assuming the same 15 cm increase in height above the standing height found in layers) the estimated minimum height of a broiler when wing flapping would be 55 cm. Breeding birds, especially breeding males, are taller, estimated to be 60 cm when standing. These bigger birds will presumably also have longer wings, so the additional height needed to wing flap was increased from 15 cm to 17 cm. As a result, the estimated height of a broiler breeder when wing flapping is proposed to be 77 cm. The height of a slower-growing broiler depends on the age at slaughter, but since they can reach sexual maturity, the minimum height is proposed to be 77 cm, i.e. the same as the minimum for broiler breeder males. Accurate measurements of the height of broilers and broiler breeders are required for more precise estimates of their height when performing different behaviours.

The part of the enclosure with the lowest height should not be less than the height of the bird when standing. One could even suggest that it should not be less than the height needed for turning which, based on the estimates from laying hens (Mench and Blatchford, 2014), is 4 cm greater than the height of the standing bird. This would lead to a minimal height of 44 cm for fast growing broilers and 64 cm for slower-growing broiler and broiler breeders. Where perch and/or elevated platforms are provided, then the height above the elevated structure should be high enough to allow a perching bird to stand normally. It may not be necessary for a bird to be able to wing flap everywhere, but the usable area should be high enough for the bird to perform all natural behaviours and therefore should not be less than 55 cm for fast-growing broilers or less than 77 cm for slower-growing and breeding birds.

In any bird enclosure and also in the veranda, there a minimum height of 2 m will allow the stockperson to inspect the birds (Better Life requirements[14]). The minimal height between tiers, the minimum height from the highest tier to the roof of the barn and the height above a perch anywhere in the system, should at least allow the bird to stand and turn normally. If the area is to be included in the calculation of usable area, the minimum height of the area should allow the performance of all natural behaviours, including wing flapping, and therefore should not be less than 55 cm for fast-growing broilers and 77 cm for slower-growing broilers and broiler breeders. Two possible exceptions to this could be considered. The area under the ramp that is the height of a standing bird may still be included in the usable area calculation. This is because it is considered important to provide ramps up to elevated areas. Although the area under chick brooders is also likely to be less than minimum height proposed, it could still be used in the calculation of useable area, since this area is intended for rest and since brooders are only used for young birds.

3.5.1.3. Minimum usable area

The area that broiler chickens use is not only influenced by the space that is available to them but also by various other factors. The physical ability of the birds can be a limiting factor as fast-growing broilers from a certain age and body mass are inactive and move very little besides going to the feeders and drinkers. However, this inactivity leads to serious WCs like locomotory problems and the 'inability of exploratory and foraging behaviour', so locomotion needs to be encouraged. The factors influencing the use of an area are group size (Channing et al., 2001), stocking density (Estevez et al., 2005), enrichment (Leone and Estévez, 2008) and the total size of the usable area (Newberry and Hall, 1990; Estevez et al., 1997). Under conditions with panels and similar enrichment items, indoor kept three-week old male broilers may use an area of as little as 3.1 m^2 (Leone and Estevez, 2008) but locomotion in general should be encouraged to avoid health problems in these birds. When offering an outdoor range, which increases both the area available to the animals and the motivation for exploration, slower-growing broilers with a better physical ability and outdoor access have greater home ranges of up to 23–29 m^2, which increase with age (Rodriguez-Aurrekoetxea et al., 2014). Therefore, an indoor minimal usable area of 23 m^2 for fast-growing and 29 m^2 for slower-growing hybrids should allow birds to perform their behavioural needs. It has been shown that fast-growing Ross 308 broilers that range outside for more than 2.7 m from the barn in an area with artificial shade and trees have better gait scores, as well as lower corticosterone levels after handling than broilers ranging less (Taylor et al., 2020). Therefore, in addition to the indoor area that is permanently available to the birds, an outdoor area that enables the broilers to range at least 2.7 m away from the barn should stimulate their locomotion and improve their leg health.

Breeders may be compared to laying hens in terms of age. Compared to broilers, laying hens have much larger home ranges of about 80 m^2 in the barn and between 450 and 1,100 m^2 in the outdoor range (Rodriguez-Aurrekoetxea and Estevez, 2016). Breeders may even move more than laying hens because they are feed restricted and may be exploring a larger area while seeking for food. However, since offering more space than provided for laying hens will not decrease the feeling of hunger in breeders, the minimum space requirement is likely to resemble the one of laying hens.

3.5.1.4. Light

Different components of light provision may affect broiler welfare, light intensity, provision of daylight, light spectrum, flicker frequency, as well as light period. Detrimental effects on welfare were predominantly found for very low light intensities (below 5 lux), as due to impaired scotopic vision chickens will show reduced behavioural activity. Chickens might also prefer certain light qualities for specific behaviours or functional areas but knowledge on preferences is limited. Preferred light intensity might vary from 0.2 lux for inactivity up to 1.000 lux for locomotion and foraging (van der Eijk, 2022b). Especially natural light increased activity, decreased lying and improved gait scores in terms of leg health (Bailie et al., 2013). Light spectrum including UV as it is provided by natural daylight was also found to promote the diversity of natural behaviours in general (Rana and Campbell, 2021). Comfort and foraging behaviours might be increased under light intensities of 50 or

[14] Criteria for broilers for Better Life label (Beter Leven keurmerk), the Netherlands.

200 lux (Alvino et al., 2009), but age and circadian effects may still have a stronger influence on chicken behaviour.

Broilers preferred 20 lux over 5/10 lux (Raccoursier et al., 2019). Also Rault et al. (2017) compared behaviour and welfare of birds at 5 and 20 lux. They found that broilers kept at 20 lux compared to those kept at 5 lux were found to be more active, had slower growth, and had lighter eye weight as eye weight increases with decreased light intensity. But other welfare measures reflective of biological functioning or leg health did not show significant changes. Blatchford et al. (2009) also studied the effect of 3 light intensities (5, 50, and 200 lux) on activity patterns, immune function, and eye and leg condition of broilers. Broilers reared with 5 lux were less active during the day than with 50 or 200 lux and showed less change in activity between day and night than with 50 or 200 lux. There was no difference between treatments for final body weight or for most immune parameters. Birds from the 5 lux treatment did have heavier eyes. A follow-up study showed that the 5 lux broilers spent more time sleeping and less time preening and foraging than broilers in the 50 and 200 lux treatments, respectively (Alvino et al., 2009). During the scotophase (i.e. the dark period), however, they spent more time performing active behaviours such as eating, walking and foraging than in the 50 and 200 lux treatments, respectively (Alvino et al., 2009). Deep et al. (2010) compared different light intensities in broilers (1, 10, 20, and 40 lux) and only found negative effects of the lowest light intensity of 1 lux, with more FPD and heavier and larger eyes, similar to (Blatchford et al., 2009). In addition, Deep et al. (2012) showed that birds exposed to a light intensity of 1 lux rested more and preened less, potentially indicating reduced activity and impaired welfare. No differences were found between the other light intensities. Kristensen et al. (2006) also studied behaviour of broilers under different light sources (warm white and biolux light) at 5 or 100 clux (chicken lux, which is light intensity adjusted according to the spectrum visible to the chicken). Broilers showed a resilient time-budget across light sources and intensities, whereas age and time-of-day affected most behaviours recorded. The birds spent 61% of their time resting in the litter at 6 weeks of age but resting was not significantly affected by light source or illuminance. However, the broilers showed less feather-pecking behaviour in warm-white rather than biolux light and more foraging behaviour in dim rather than bright light intensities. In a study where behaviour was monitored during switches between 5 and 100 lux, it was observed that the broilers showed significantly higher activity during periods of 100 lux than 5 lux when intensity alternated. Activity decreased with age but not with experience of the light regimes. The broilers responded significantly faster to a step-up than to a step-down in light intensity.

The preference of the broilers for light intensity may dependent on the performed behaviour or functional area in the barn. (Pan et al., 2019) reflected by an increasing activity and feed intake with increasing light intensity. At the same time, it has been shown that increased light intensity decreased fear responses in broilers (Mohamed et al., 2020). Natural day light might increase light intensity by 600 times resulting, e.g. in 6,000 lux but still, the impact on behaviour has to be further investigated (Linhoss et al., 2022). More knowledge might be available for the appropriate light spectrum. Whereas broilers were found to show more comfort behaviours in blue and green light, more discomfort and aggression was found under white light conditions (Lucena et al., 2020) and more locomotion under red and yellow light (Sultana et al., 2013). The full daylight spectrum composition including UV might contribute to broiler welfare (de Jong and Gunnink, 2019) as it has also been shown for laying hens (Wichman et al., 2021). There might also not be a difference between broilers and laying hens according to the flicker frequency as the threshold for both has been reported around 83 Hz (ranging from 69 Hz to 95 Hz), resulting in at least 95 Hz to be desirable (Nielsen, 2020). Data for the desirable light program are surprisingly rather limited. Schwean-Lardner et al. (2012) have shown that 16- to 17-h light and 7- to 8-h dark period might support broiler welfare. However, more research on more optimal light conditions is needed.

To mimic the natural brooding of a hen, an intermittent light program has been under discussion for a long time for chicks, although it is not commonly implemented in practice (Buyse et al., 1996). More research is needed as the effect on welfare is still discussed.

3.5.1.5. Temperature (Specific ToR 1a)

As described in Section 3.4.2.3, it is important to provide day-old chickens with the appropriate air (30–35°C) and floor (28–30°C) temperature in the barn upon placement and during the first days of life to prevent cold stress, which may eventually lead to increased mortality. To achieve this, the barn containing the litter should be pre-heated 48 h before placement so that the floor and the litter have the time to reach appropriate temperature. If spot brooding is applied, the temperature under the brooder should be 32–35°C (chickens can choose their preferred temperature zone with spot brooding). Farmer's management is therefore crucial. Frequent checks of the chickens during the first days of life to check for indications of cold stress are needed. Corrective actions include increasing the environmental temperature and adjust ventilation (to prevent draught).

Thereafter, the required minimum temperature should gradually decrease until the recommended values of 17–21°C for chickens older than 28 days of age onwards are reached (management guides Aviagen (2018a), Hubbard (2022), Cobb (2021), Sasso (2022) and Section 3.4.2.3 on 'cold stress'). These are the advised temperature ranges by the breeding companies, and below and/or above these temperatures broilers may perceive cold or heat stress. Generally, it is indicated that fast-growing chickens need slightly lower minimum temperature at older ages than slower-growing chickens, although this is dependent on body weight, age, stocking density (Cobb, 2021), humidity, wind speed, and the specific hybrid. For broiler breeders, the decline in recommended environmental temperature is equal or a bit slower, depending on the breed (e.g. dwarf breeders, 25–26°C at 35 days of age) (Aviagen, 2018a; Hubbard, 2022; Sasso, 2022).

For older broiler chickens in mobile systems with an outdoor area, there is a risk for cold stress if the outside temperature is very low, e.g. there is a risk for frost bites on the comb during winter. These chickens should be provided with heating system in the mobile house during the rearing phase that can always be accessed by the broilers to ensure an environmental temperature as indicated above. Litter on the floor also provides insulation and farmers can select the location of these houses in such a way that the risk for cold stress is minimised (see Section 3.4.2.3).

Broiler chickens in mobile systems with outdoor range are also at risk for heat stress. The higher the age, the lower the upper critical temperature for heat stress. In young chicks, heat stress may be present from 35°C onwards; and in older chickens, it is reported that chickens are at risk from 28 to 30°C onwards (Akter et al., 2022, moderate heat stress). However, the threshold for heat stress is dependent on many factors such as humidity, body weight, stocking density, age and hybrid, degree of adaptation and the duration of exposure (see Section 3.4.2.9). Slower-growing chickens are usually less at risk for heat stress, due to a lower metabolic rate as compared to fast-growing chickens (de Jong et al., 2012a). In mobile houses with outdoor range, there is a risk for heat stress due to poor ventilation and sunshine on the mobile house. Farmers should consider where to place the mobile house in summer period to prevent heat stress and ensure proper active ventilation inside. In the outdoor range, shelter (preferably natural shelter) should be provided to prevent heat stress during hot days (see Section 3.4.2.9).

Broiler chickens and broiler breeders can have difficulty dissipating heat from the body when sitting on the litter. Raised wire platforms or perches may help to dissipate heat from the body by escaping from the warm litter (Gebhardt-Henrich et al., 2017b).

In indoor systems, pad-cooling systems should be installed to prevent heat stress during hot days in summer. Further, reducing stocking density will help to reduce the risk for heat stress in indoor systems (see Section 3.4.2.9).

It is assumed that broilers are able to cope with short periods of heat and cold by adapting their behaviour so that their core body temperature is not affected. However, with long duration or very high or low temperatures heat or cold stress may occur. Generally, applicable thresholds for either heat or cold stress cannot be defined, as these are dependent on factors such as humidity, air speed, hybrid, stocking density, body weight, age, degree of adaptation and duration of exposure. Regarding cold stress, broilers can tolerate a low temperature due to the insulation of their feather cover, skin fat deposits and high volume to surface ratio (Yahav et al., 2009), and they will restrict the period being outside when it is too cold. Thus, in mobile systems with an outdoor range, broilers will move inside to prevent cold stress, and therefore an indoor heated area should be available in winter.

3.5.1.6. Air quality and dust (specific ToR 1d)

Air quality is fundamentally important for both the poultry and the farmers working in the barn. Chickens have respiratory tracts that differ from those of humans, in which air sacs ensure that air continuously flows through the lungs. However, the environment in which the animals are kept produces emissions that are harmful for animals, humans and the environment. In the barn, the animals are mainly exposed to ammonia (NH_3), carbon dioxide (CO_2) and dust.

Ammonia is the main emitted pollutant gas from poultry farms (Adler et al., 2021). Ammonia is formed when protein from the excreta of the animals is converted by microorganism into NH_3 together with water from moist litter. A too high concentration of NH_3 in the ambient air can irritate mucous membranes, including the conjunctiva, and promotes the proliferation of coccidia, clostridia, and other bacteria in broiler. However, ammonia is especially harmful to the respiratory organs, which can be damaged. This is especially the case when concentrations exceed 30 ppm (Miles et al., 2004). In this context, it is important that air concentration is measured at the animals' head height. The legally prescribed maximum value in many countries is also set at 20 ppm ammonia in the stable air, as in the Council Directive 2007/43/EC[5].

ABMs have been described by Liu et al. (2021b). The authors showed that head shaking correlates significantly with the increase in ammonia concentration. Compared to an ammonia concentration of 0 ppm, chickens increased their head shaking significantly at 15 ppm, while losses in performance were only visible at 35 ppm. The higher the concentration, the more the animals shook their heads. With an increase in ammonia concentration, average daily feed intake, average daily gain, and feed/gain also decreased. In all cases, 0 ppm ammonia was optimal for the welfare of animals. More detailed thresholds would be desirable but are not available currently.

Preventive measures that contribute to a reduction of ammonia concentration, by improving litter quality, are:

- forced ventilation
- drinking system without leakage
- heated floor
- raised levels with manure belt and manure belt ventilation
- targeted selection of the litter materials

Corrective measures are mainly focused on increased ventilation and re-littering or at least adding new litter. The lower the concentration of NH_3, the better for the animals. Corrective measures should be initiated at 15 ppm already, which is lower than the present maximum in legislation (20 ppm). More research could model animal-based limits based on NH_3 values.

The concentration of ammonia is influenced by various factors, including air temperature and humidity, air velocity, litter material and temperature, dry matter content and pH of the litter. Ideally, a dry matter content of more than 75% and a pH below 7 should be maintained. The combination of litter and pH-value as well as stocking density and bird diet (protein content) impacts, amongst others, the ammonia concentration already present in the barn (Miles et al., 2004).

Carbon dioxide is also a common gas present in broiler housing, partly because heating is often done with gas cannons and partly because of decomposition processes in the litter; independently, the broilers themselves emit CO_2 while breathing. The problem with carbon dioxide is that it accumulates on the floor near the animals because the gas is heavier than the ambient air. In the worst case, CO_2 hinders the absorption of oxygen in the organism, which can lead to increased mortality. For this reason too, it is essential to ensure adequate ventilation.

There is also a threshold value for CO_2 in the current legislation (the Council Directive 2007/43/EC[5]), which is 3000 ppm (0.3%). Anderson et al. (1966) found no harm on the lungs of broilers that were exposed to 5000 ppm of CO2 (0.50%) for 8 weeks. Creach et al. (2022) report 0.11% being the average in a commercial setting in a summer production period, whereas the CO_2 level increases to 0.29% in a winter production period. This difference is due the heating system which is used in winter to remove humidity from the barn air and that produce CO_2 (gas heating) (Corkery et al., 2013). Increased CO_2 levels can be prevented as well as corrected by functional ventilation, which exchanges the air in the barn via previously tested airflows without causing draughts for the animals.

Dust is present in the barn, which is primarily composed of litter, feed and dried excrement and feather. Dust can obstruct the respiratory tract and may act as a vector for fungal spores among other things and, independently of this, can burden the respiratory tract of animals and humans. Dust is classified according to particle sizes. The size classes have a physiological subdivision (for humans). Thus, particle sizes $\leq$ 100 μm are inhalable and deposit in the mouth and nose; those $\leq$ 10 μm are thoracic and deposit in the larynx and lungs, and those from 4 to 10 μm are tracheobronchial and deposit in the trachea and bronchi; the particles $\leq$ 4 μm are respirable/alveolic and deposit in the alveoli. There are legal requirements for the air leaving the barn. In Germany, for example, no more than 0.20 kg/h or 20 mg/m^3 may leave the barn as dust emissions. In general, dust concentrations have to be kept at a level which does not harm the chickens according to legal requirements (European Commission, 2005a). Dust might be difficult to measure and is bonded in exhaust systems reducing the environmental impact. However, this does not lower the impact of dust on the birds inside the barn. In studies measuring dust concentrations in the barn, a mean of 5.31 mg/m^3 has been reported (Carpenter, 1986; Takai et al., 1998; S. Redwine et al., 2002; Homidan et al., 2003; Vučemilo et al., 2008). The measured total dust content varied in the studies between approx. 1 and 10 mg/m^3

and is therefore very variable. However, this is mostly due to non-standardised test procedures, and to the dependence on the activity of the animals that stir up the dust.

Although, there is no quantitative threshold for dust concentrations, a qualitative approach to dust measurement is given in the Welfare Quality Assessment Protocol for Poultry (Welfare Quality®, 2009). In a dustsheet test, a black A4 size paper is placed horizontally above bird heights. The dust level found on the paper can be classified by a: none, b: little or thin covering and c: a lot of dust or paper colour no longer visible. To prevent dust, the choice of litter material and its processing method is crucial. In general, using de-dusted litter is a major advantage, which is not generally applied in practice. Other technical measures mitigating high dust levels in the barn are water spraying (which might have other negative consequences) and increased ventilation.

An overview of various aspects of air quality is given by Huang and Guo (2019, 2020). Their investigations in broiler houses showed typical concentrations of NH_3 of 17 ppm, mean CO_2 concentrations of 2,372 ppm and respirable dust concentrations of 0.45 mg/m^3. However, the authors also point out the dependence of these concentrations on the time of day and especially on the season.

3.5.1.7. Group size

Broiler chickens are kept in large groups (> 25.000) but in some cases, such as broilers kept in mobile systems or breeders kept in cages, the group may be much smaller (< 300). In contrast to the link between stocking density and the risk of a range of different WCs, which are supported by a large volume of literature, the link between maximum group size and WCs is much less clear and seems less important than stocking density (Leone and Estevez, 2008; Leone et al., 2010). There is very limited evidence from one study that when kept at group sizes of 3,000 and 4,000, birds showed reduced FPD, hock burns and breast burns than broilers kept in group sizes of 6,000 and 20,000. The authors attributed this to a more unequal distribution of birds and therefore unequal accessibility of resources in larger groups (Sarıca et al., 2022). The same is likely to be applicable to breeders and slower-growing hybrids.

More research is needed on the impact of group size on chicken welfare in general to be able to recommend a maximum group size.

Minimum group size

Birds are social animals, therefore should not be housed alone. A minimal group size of two is therefore necessary to avoid isolation stress (Marx et al., 2001). However, considering the complex social behaviour, especially the formation of a pecking order, a bigger group size should be recommended, for example at least 4–5 chickens should be kept together. A minimum number of individuals allowing chickens the expression of complex social behaviours cannot be derived from the literature (Estevez et al., 1997). Observations of perch-related antipredator behaviour in young domestic fowl decrease with increasing group size (15, 30, 60 and 120 birds), implying that birds in larger groups may feel more secure during resting (Newberry et al., 2001). The threshold where increasing the group size no longer reduces fear is unknown. Other behaviours such as foraging in the free-range area are socially facilitated and will be supported by larger group sizes (Newberry et al., 2001).

Maximum group size

It is agreed that there should be a maximum group size in order to avoid negative impact on welfare (e.g. due to group stress). Scientific studies on the topic are limited, but one study showed an increased prevalence of FPD, hock burns and breast burns when broilers were kept in group sizes of 6,000 birds or more (Sarıca et al., 2022). As this evidence comes from only one study focussing on the effect of group size, more research is needed to understand the underlying mechanisms of large groups and how group size affects welfare. A historic study showed that chickens are capable to remember 96 individuals which is the prerequisite for a stable pecking order (Guhl, 1953). Whether this number of animals is still valid or even applicable to current broiler hybrids, remains unknown. In addition, it is not clear how important a stable pecking order for large groups of broiler and broiler breeders is. Studying large chicken groups is in reachable sight as RFID technique amongst others is now wearable also by small chickens.

No maximum group size was identified in order to prevent welfare impairment.

3.5.1.8. Covered veranda

The veranda is a non-heated area adjacent to the barn, accessible to the birds via popholes in the side of the barn and partially exposed to the outdoor environmental conditions. A covered veranda has a roof, is separated from outdoor by windbreaks, at least on one side (EFSA AHAW Panel, 2023) (see Section 3.3.4) and the floor is covered with litter. A common size of the veranda is at least 20% of the indoor usable floor area (e.g. Better Life requirements[14]) or 10% of the indoor usable floor area in Switzerland (Ordinance 910.13 of the Swiss Federal Council[15]); as the veranda has for objective to provide extra space to chickens and is not accessible all the time, it should not be counted as usable area. The primary purpose of the veranda is to provide conditions that facilitate foraging, exploratory and dustbathing behaviour and to provide the broilers with extra space, and to give the broilers a choice for daylight, sunlight and different temperature conditions (see Section 3.3.4; Riber et al., 2018). A veranda is beneficial for both broiler chickens and broiler breeders, although it is currently not frequently used for breeders. In systems with an outdoor area, access to a veranda can act as a transition environment facilitating a better use of the outdoor area (EFSA AHAW Panel, 2023). A veranda can also minimise disruption and frustration for birds if outdoor range access has to be restricted due to disease risk (e.g. avian influenza) or adverse weather. The use of an outdoor area in conjunction with a veranda will mitigate many of the effects of adverse weather conditions such as wind and rain (EFSA AHAW Panel, 2023). In an indoor system, a veranda provides an area promoting natural behaviour of the chickens. Usually access to a covered veranda is provided from 21 days of age onwards in broiler chickens, but when the design is such that also young chickens can use the popholes and easily go back to the indoor house there is no reason not to provide earlier access from day 14 of age onwards.

A veranda having a minimum height of 2 m allows a stockperson to inspect the veranda (e.g. Better Life requirements[14]). A veranda providing with dry friable litter will stimulate foraging. Access to natural light and fresh air from at least one wall (preferably along the length of the house) (e.g. Better Life requirements[14]) will stimulate exploration and other behavioural needs by allowing the bird to access different light and temperature range. Provision of enrichments such as bales, foraging materials and other pecking substrates will encourage foraging and exploration. Good drainage of the floor in the veranda is necessary to prevent litter from getting wet and caked (see Section 3.4.2.17 and EFSA AHAW Panel, 2023).

An access to the veranda for at least 8 h per day when the duration of the daylight period is 8 h or longer, or during the daylight period with a shorter duration of daylight such as in winter in Northern countries will allow birds to perform exploration, foraging and other behavioural needs during all their period of activity. As the popholes affect the ventilation of the indoor barn, it might be necessary to adjust the ventilation system if a covered veranda is added to an existing indoor barn, and considering the veranda in the ventilation plan when building a new barn will prevent thermal stress to the birds.

The design and disposition of the popholes giving access to the covered veranda will influence its usage. A good condition of the litter (dry and friable) near the popholes will also promote pophole use. If a covered veranda is to be used in multi-tier systems for layers, popholes accessible from both sides of the house (EFSA AHAW Panel, 2023) will enable all birds to use the veranda. Verandas can be also used to improve the welfare in broiler breeder multi-tier systems. If the distance to the popholes is too long, it will enable some chickens to use the popholes, e.g. the Better Life requirements[14] in the Netherlands advise a maximum of 25 m distance for broiler chickens and in Switzerland, the distance should not be more than 20 m (Ordinance 910.13 of the Swiss Federal Council).

From layer studies, it is known that the number of hens using the range increases with greater pophole width per bird (Sherwin et al., 2013; Gilani et al., 2014). Also, some birds will sit in the popholes or block the entrance. Therefore, a sufficient length of popholes is necessary to allow the frequentation of the veranda by all birds. For broiler chickens, it is, e.g. advised by different quality schemes to have at least 1 m per 1000 chickens (e.g. Better Life requirements[14]) evenly distributed over the long length of the house, or 2 m per 100 m^2 of the barn with a width of at least 0.7 m (Ordinance 910.13 of the Swiss Federal Council[14]) but more research is required for optimal pophole design for broiler chickens. For broiler breeders, the requirements of layers can be adopted until more research from broiler breeders is available (EFSA AHAW Panel, 2023). Popholes should not be too high (from the ground) young chickens can easily enter the covered veranda. For layers, a maximum height

[15] Ordinance 910.13 of the Swiss Federal Council of 1st January 2022 on the conditions and procedure for direct payments in agriculture (Ordonnance sur les paiements directs verses dans l'agriculture). pp. 96–97.

of 25 cm from ground level is advised which can also apply to broiler breeders (EFSA AHAW Panel, 2023).

If it is impossible to have a covered veranda attached to the barn (e.g. because of the absence of space with existing buildings), some of the advantages of the covered veranda in terms of broiler welfare, in particular the additional space, can be provided by giving the broilers 20% additional space indoors with reference to the minimum space allowance.

3.5.1.9. Outdoor range

Access to an outdoor range provides broilers and broiler breeders with opportunities to perform their natural behaviours, particularly exploration, foraging, dustbathing and sunbathing. The additional space encourages locomotor behaviour. Altogether, this results in an increased likelihood of fulfilling the behavioural needs of the broilers and broiler breeders as compared to chickens housed in indoor systems or indoor systems with a covered veranda only. Although outdoor access may be direct from the indoor house by popholes in the wall of the house, having a covered veranda in between as a transition zone will favour access to outdoor. Especially in adverse climatic (wet) conditions, this transition zone will prevent wet litter inside the barn. Outdoor ranges are not common for broiler breeders but are widely used in organic and free-range production systems for broiler chickens, usually combined with a slower-growing genetic hybrid.

Regarding laying hens, early experience in accessing the free-range determine the birds´ frequency and proportion of the area used later in production (Rodriguez-Aurrekoetxea and Estevez, 2016), and likewise, this may affect the extent to which broiler breeders will use the outdoor range in the production period, although there is no information available regarding broiler breeders.

Regarding outdoor range use, there is a large variation in range use between broiler hybrids, with slower-growing broiler hybrids generally showing better range use than fast-growing hybrids (Nielsen et al., 2003; Sarica et al., 2019). Within hybrids, there are large individual variations in range use within and between flocks with some individuals never accessing the veranda or the free-range area, while others can be described as heavy users (Rault and Taylor, 2017; Taylor et al., 2017a; Marchewka et al., 2020). Range use in broiler chickens is affected by season/weather (lower range use in wet, cold and/or windy conditions) (Rault and Taylor, 2017; Stadig et al., 2017b; Taylor et al., 2017b; Taylor et al., 2018; Sarica et al., 2019; Marchewka et al., 2020), presence of shelter (higher range use with dense natural vegetation, (Stadig et al., 2017b; Stadig et al., 2018)) and accessibility from the indoor house (higher range use when the range was accessible from both sides of the house (Rault and Taylor, 2017)). Also, bird-specific factors such as walking ability affect range use, with lower use correlated to higher (worse) gait score of chickens (Taylor et al., 2018). Range use is highest in the morning after opening the range and at the end of the day before closing the range (Taylor et al., 2017b).The quality of the range can greatly influence its usage and the health of the birds (Maurer et al., 2013). A good distribution of birds on the range use greatly reduces the risk of helminth infection. Range use is promoted by providing sufficient cover, which should preferably be natural cover such as trees, bushes or tall grasses (Dal Bosco et al., 2014; Stadig et al., 2017b), and a good distribution of birds on the range is promoted by cover evenly distributed over the range (EFSA AHAW Panel, 2023). Natural cover is also preferred in case of hot weather conditions (see Section 3.4.2.9). No literature exists on the minimal percentage of the range that should be covered by vegetation and bushes/trees. As a guideline to how an attractive outdoor range can be designed, the Danish regulation[16] may be applied which states that 70% of the range should be covered with vegetation of which 50% should be with trees and/or bushes so that corridors are formed. According to a Danish guidance,[16] the distance between the first vegetation and pophole should be 25 m maximum, and between the trees and/or bushes the distance should be maximum 20 m. This increases the chance that the entire outdoor range is regarded as attractive and therefore stimulates high use and an even distribution of chickens. The Danish farmers report that this works well in practice (Riber, personal communication, 8 November 2022). The use of enrichment such as alfalfa has been reported to also promote the use of the outdoor range in broilers (Riber et al., 2018).

Regarding access to the range and pophole requirements, the same requirements are valid as described for the covered veranda. Access to an outdoor range is usually provided from 3 to 4 weeks of age onwards. However, when the design is such that also young chickens can use the popholes and easily go back to the veranda and to the indoor barn there is no reason not to provide earlier access

[16] Guidance on organic agricultural production of the Ministry of Food, Agriculture and Fisheries of January 2022 (Vejledning om økologisk jordbrugsproduktion).

(from 21 days of age onwards the latest). The outdoor range should be accessible for the chickens during daytime.

3.5.2. Equipment

3.5.2.1. Perches

The EFSA AHAW Panel (2015) defined three meanings of the term 'perching' that are relevant regarding the question what is an adequate perch: 'First, birds can be said to perch on structures (rods, poles, branches) that they can grasp with their feet. Second, birds can be said to perch on the edge of structures from which they have a vantage point and can survey their surroundings. Third, birds can be said to perch on structures which are elevated'.

All adult chickens use perches especially at night, and because of their strong motivation for night time perching, this has been considered a behavioural need for chickens (Weeks and Nicol, 2006). Since fast-growing broilers are slaughtered before or just reaching the age when chicks would start night time perching in nature (around 5–6 weeks, (McBride et al., 1969)), different preferences for resting and night time roosting might apply when compared with adult birds. In general, perches have to be elevated because height is more important than shape for Gallus (Schrader and Müller, 2009) which supports the hypothesis of an anti-predator function of roosting on perches.

As adult chickens want to use perches and roost at elevated positions, the provision of perches is mandatory in the EU for laying hens (Council Directive 1999/74/EC[2]). In the EU, the provision of perches is not regulated for broilers and broiler breeders, and data on perch use of broiler breeders are scarce. Perches are required for breeders (of layers and broiler) in some European countries though the application to poultry other than layers is inconsistent (EFSA AHAW Panel, 2010).

The provision of perches during rearing of broiler breeders is recommended by the breeding companies like Aviagen (management guide Aviagen (2018a)). The use of perches during the rearing period trains the females to reach the nest boxes and thus reduce the incidence of floor egg laying later during production (Brake, 1987). Moreover, perches have an apparent fear-reducing effect, as shown by shorter tonic immobility in broiler breeders reared with perches in comparison to those reared without perches (Brake et al., 1994). Elevated perches can also improve the physical development of broiler breeders by increasing jumping and flying behaviour (Gebhardt-Henrich et al., 2017b). However, roosting on inappropriate perches (e.g. round steel) might result in the development of breast blisters (Nielsen, 2004). There is a preference of broiler breeders for wooden slats instead of perches (Mens and van Emous, 2022). Therefore, broiler breeders incl. the pullets can be kept in (adapted) aviaries with perches incorporated in wooden slats comparable to laying hens. This applies to the fast-growing Ross 308 as well as slower-growing hybrids like Sasso (Gebhardt-Henrich et al., 2018). Although, from their body dimensions, broiler breeders would need about 22 cm perch length (Brandes et al., 2022), no difference in the number of breeders perching at night was found when offering 14 cm per bird and 20 cm per bird but fewer breeders perched when only 10 cm perch length was available per bird (Gebhardt-Henrich et al., 2017b).

Perch width and shape influence their use in laying hens (Skånberg et al., 2021). Unfortunately, there are hardly any studies about the preference for material and shape of perches for broiler breeders. A mushroom shaped plastic perch that is 15 cm high and 8 cm wide is on the market for broiler breeders (Siesta L3000, Big Dutchman). In a choice study with commercially kept broiler breeders this was the preferred perch over steel round, steel square, and wooden perches but perch type and location (height) were confounded (Vasdal et al., 2022b).

3.5.2.2. Tiers/Platforms

Due to the early slaughtering age of broilers and the weight of the breast muscles, fast growing broilers do not use perches very much (Norring et al., 2016; Bailie et al., 2018b; Spieß et al., 2022b). But when perches are offered and used, the morphometry of fast-growing Cobb broilers is changed as shown by Nazareno et al. (2022). Unfortunately, in this study, the use of the perches was not quantified.

Since (most) broilers, especially fast growing, do not perch very easily, other elevated structures like tiers and platforms can be used to add complexity to their environment (enrichment) and offer an elevated position. Elevated structures encourage locomotion (Malchow et al., 2019b) and decrease the risk for locomotory problems by separating the animals from any wet litter (Bizeray et al., 2002; Kaukonen et al., 2017b; Mocz et al., 2022); see reviews by Riber et al. (2018) and Pedersen and Forkman (2019). Elevated structures also satisfy the need of the birds for elevated positions to escape perceived predation stress and thus offer an alternative to perches. Ramps at an angle of about 15°–35° help fast growing broilers to access elevated structures (Malchow et al., 2019a; Tahamtani et al., 2020). In a review, Pedersen and Forkman (2019) recommended that elevated structures should not be higher than 10 cm (Norring et al., 2016) or otherwise, it should be equipped with a ramp. In slower-growing broilers and broiler breeders, however, perches will be useful to prevent inability to perform resting behavior (Gebhardt-Henrich et al., 2017b; Gebhardt-Henrich et al., 2018; Göransson et al., 2021), see Section 3.5.2.1.

In Switzerland, about 90% of fast-growing broilers have access to elevated plastic grids as platforms covering 10% of the floor area in stocking densities of 30 kg/m^2 (Gebhardt-Henrich et al., 2021). Much more, namely 50% of the floor was covered with partially raised plastic slats in the study of May et al. (2022). More birds were observed on the plastic slats than on the littered floor, probably because food and water was located there in contrast to the Swiss barns where platforms are bare. In the study by May et al. (2022), birds were mainly inactive when sitting on the slats. This can be positive by reducing disturbances of resting animals (Yngvesson et al., 2017) but a large litter area is also needed additionally to encourage locomotion and meet behavioural needs like dustbathing, foraging, and scratching. It is important to note that free area under the platform is also available as platforms and ramps to access the platforms will reduce the usable area and the light that reaches the floor.

3.5.2.3. Litter

Litter quality is one of the most important parameters determining broiler welfare (Dawkins, 2004; Çavuşoğlu and Petek, 2019). Dry and friable litter enables the birds to display their natural behaviours like foraging and exploration, including scratching, and dustbathing (Chuppava et al., 2018). The ability to fulfil behavioural needs is a central part of animal welfare and if this is taken into account the area of litter should therefore be sufficient for all birds to access it (see review by Mace and Knight (2022)).

Besides enabling natural behaviour, one of the main functions of litter is to absorb moisture, store it, and then to release it (Dunlop et al., 2016) so remaining dry and friable. However, according to Shepherd and Fairchild (2010), in practice litter consists of a mixture of bedding material, excrements, feathers, wasted feed, and moisture and after day 14 it mainly (80%) consists of excrements and wasted feed (Kamphues et al., 2011). This mixture releases NH3 when animals scratch in it and the contact with this material can lead to the development of hock burn and pododermatitis and a general decrease in welfare (de Jong et al., 2014). Therefore, a slatted area below the feeders and drinkers can help to maintain litter quality (Adler et al., 2020). Sufficient depth of litter (enough to isolate bird from the floor, retain feces and allow birds to forage and explore but also not too deep in order to allow humidity evacuation (Shepherd et al., 2017)), appropriate litter treatment, like litter turning, and a good ventilation system are all decisive for maintaining litter quality (Pepper and Dunlop, 2021). For an overview about good litter management promoting health and welfare in broilers see the systematic review by Sargeant et al. (2019).

3.5.2.4. Nests for breeders

A nest can be defined as a separate space destined for egg laying. Nesting behaviour is among the highest motivated behaviours in laying hens (EFSA AHAW Panel, 2005; Weeks and Nicol, 2006). Before laying, i.e. oviposition, hens will search for a suitable nest site and perform nest building behaviour. Egg laying is followed by a resting period within the nest. There seems to be a certain motivation for searching for a nest site and a separate motivation for nest building (Cooper and Appleby, 1996; Cooper and Appleby, 2003). There is no biological reason and no evidence that nesting behaviour is different for female broiler breeders than for laying hens.

The hens' acceptance of the nests is crucial to prevent eggs being laid outside the nest, so-called floor eggs. Laying eggs in the intended nests also indirectly imply that the nest location and design satisfies the nest searching motivation of the bird better than any other location. The attractiveness of nests is affected by a variety of features. In general, laying hens prefer enclosed nests (i.e. covered from both sides, the back and the top) compared to more open nests (Appleby and McRae, 1986). However, enclosure does not need to imply low light. (Appleby et al., 1984) found that although there was some effect of the maturity and earlier experience of the hen, light intensity was not a fundamental factor affecting nest selection. Podkowa and Surmacki (2017) albeit working with wild birds, tested the hypothesis that considering the importance of light on development of the embryo and given that eggshells are transparent, birds would choose nest boxes with elevated brightness, which they did. Birds often prefer the nests on the higher row(s) compared to the lowest row

(Lundberg and Keeling, 1999). Nests at the ends of the row are also chosen more often (Riber, 2010; Clausen and Riber, 2012). When the floor is sloping, which is common to allow eggs to roll away to the egg belt for collection, hens prefer a less sloped floor (Stämpfli et al., 2011).

Laying hens prefer substrate in the nest which they can mould with their body and feet, and which allows them to perform nest-building behaviour (Duncan and Kite, 1989). Thus, substrates such as straw and oat husk are more suitable compared to surfaces such as a plastic floor, synthetic grass or wire mesh (Huber et al., 1985; Struelens et al., 2005; Struelens et al., 2008). Birds appear to value the protection by the more closed front of the one-piece curtain flap at the front of the nest, but the sliced curtains provide an easier access for birds to visit and inspection of the nest (Stämpfli et al., 2012). There is a preference for small compared to large group nests or if large group nests are divided by a partition into two halves (Ringgenberg et al., 2014; Ringgenberg et al., 2015). In floor housing systems, access to nests can be improved using platforms in front of the nests compared to perches (Stämpfli et al., 2013). Lentfer et al. (2011) recommended that in aviary systems with integrated nests, the platforms in front of the nests should be more than 30 cm in width. Of the few studies that have been carried out on nest preferences with broiler breeders, one found a preference for small nests (Holcman et al., 2007) and another found a preference for wooden nests (van den Oever et al., 2020b). Of importance in all studies of preferences is that the choice is relative and highly influenced by the other choices available.

The EFSA AHAW Panel is not aware of any systematic studies on the optimal number of nest boxes or nest box space allocations for broiler breeders for commercial conditions and therefore no evidence to recommend something different from what is currently applied in the field. One industry recommendation suggests 3.5–4 hens per nest hole for manual nests or 40 hens per linear meter communal nests (Aviagen, 2018b). For comparison, examples of legislation in some countries are a minimum of 0.0125 m^2/broiler breeder hen in single nests and 0.010 m^2/broiler breeder hen in colony nests[17] and 5 hens per nest and 100 hens per square m for broiler breeders, layers and layer breeders.[11] The EU legislation for laying hens is at least one nest for every seven hens. If group nests are used, there must be at least 1 m^2 of nest space for a maximum of 120 hens i.e. 0.008 m^2 per hen (Council Directive 2007/43/EC[5]).

The provision of appropriately designed and located nest sites can be considered relevant for the welfare consequence 'inability to perform exploratory and foraging behaviour', since birds explore the environment to find a nest site. It is also relevant to the welfare consequence 'restriction of movement' since a small total area, for example in cages, limits the opportunity to provide a nest.

3.5.2.5. Feeders

The situation regarding feeders is very different for commercial broilers, which have feed available almost *ad libitum* (even if they sometimes have their daily ration split into timed feeding periods), compared to broiler breeders, which are feed restricted. The restriction for the breeders is most severe during the rearing period. Birds tend to synchronise feeding behaviour (Collins and Sumpter, 2007; Keeling et al., 2017). This is more noticeable when birds are fed in meals, and very apparent when the amount of food is restricted, which will influence the amount of feeder space required. Physically, the space needed at a straight feed trough is greater than that needed at a round pan feeder.

The feeding space recommendations for commercial broilers ranges from 1.2 to 5.1 cm per bird and from 45 to 100 birds per feeder depending on age and hybrid (Li et al., 2021b). There is nevertheless rather little research systematically varying feeder space and it is not entirely obvious which outcome measure is the most appropriate when comparing different feeding space allocations. Li et al. (2021b) found that feeder utilisation was the highest with the feeder space allocation of 2.3 cm per bird at round feeders compared to larger allocations. Other work found that increasing from 2.4 cm feeder space per bird to 4.5 cm reduced agonistic behaviour during the feeding period (Olukosi et al., 2002). Purswell et al. (2021) found that bodyweight was significantly improved during the starter and grower phase as feeder space increased, but this was not the case during the finisher and withdrawal phases (comparisons were 2.3, 4.6 and 6.9 cm per bird at round feeders). Feed conversion, however, was better at 2.3 cm per bird. When investigating blood physiological variables, Olanrewaju et al. (2022a, b) found no effect of feeder space on corticosterone, thyroid or glucose levels and concluded that increasing feeder allowances did not improve welfare (comparisons were 2.3, 4.6 and 6.9 cm per bird). Details of experimental design, hybrid and age make comparisons

[17] Regulations and general guidelines SJVFS 2019:23 of 28 March 2019 of the Swedish Board of Agriculture on poultry husbandry in agriculture (Statens jordbruksverks föreskrifter och allmänna råd om fjäderfähållning inom lantbruket).

between studies difficult. All studies focused on broilers, not on breeders, for which feeder space will be more crucial. Also, it is not only the average allocation of feed space per bird that is important, but how the feed troughs are distributed in the barn. When access to the feeders was restricted, consumption, aggression, and space use increased (Leone and Estévez, 2008). Nevertheless, when the emphasis is put on the outcome indicators of bodyweight and aggression, it seems that space allowance for broilers at round pan feeders of at least 4.5 cm per bird gave the best results.

Industry recommendations for broiler breeders (unless spin feeders are used) are typically 5 cm per bird up until 5 weeks of age, increasing to 10 cm up to 10 weeks of age and 15 cm per bird after this at straight troughs (EFSA AHAW Panel, 2010) and at round pan feeders typically 4, 8, 10 cm for females and 5, 9, 11, 13 cm for males (Aviagen, 2018a). Since broiler breeders, especially during rearing, are kept on a restricted diet and fed in meals, it is particularly important that they can all access the feeder at the same time. According to Brandes et al. (2022) who measured the body width of broiler breeders at 22 weeks of age, female broiler breeders had a body width of 20.63 $\pm$ 1.88 cm and males a body width of 21.94 $\pm$ 2.32 cm. Based on this, a trough side length of 21 cm per hen and 22 cm per rooster should ensure that all broiler breeders have equal access to feed. This is greater than the 15 cm presented above, implying that the space recommendations for breeding birds at a straight trough is too low. A typical pan feeder has a diameter of 33 cm and so a circumference of approximately 104 cm. According to the industry recommendation a typical pan feeder is therefore appropriate for 10 females or 8 males. The widest part of the bird is not at the head but an estimated 15 cm further back along the body, where the circumference would be approximately 200 cm. Ten females, each 21 cm wide, would require a circumference of 210 cm at this distance from the pan feeder and 8 males, each 22 cm wide, would require a circumference of 176 cm. This implies that the industry recommendation for feeder space for females at a round feeder is approximately correspond to the physical space needed for bird to feed at the same time, giving even extra space for males. It has not been possible to find the width of younger broiler breeders or of broilers kept for meat production.

3.5.2.6. Drinkers

Most farms use cup or nipple drinkers rather than bell drinkers since they are easier to keep clean. Whatever the system, it is important that they are well-maintained and do not contribute to wet litter. In the Welfare Quality broiler protocol (Welfare Quality®, 2009), the recommendation is 10 birds per nipple, 28 birds per cup and 100 birds per bell drinker. However, in the study by Buijs et al. (2017) nipple ratios up to 19 birds per nipple drinker were noted without observed obvious behavioural signs of a shortage of drinkers (e.g. queueing or agonistic interactions around drinkers). This supports other work showing many factors in addition to drinker allocation affect water intake, e.g. Feddes et al. (2002) found no difference in water intake between birds with drinker ratios of 5 and 20 and Houldcroft et al. (2008) concluded broiler chickens prefer drinkers to be at a lower rather than higher position to drink, corresponding to the natural 'scoop' action of drinking. Height of the drinker is important, but mainly to ensure that small or lame birds can reach the drinker. Given that broilers show decreasing locomotory activity, it is important that drinkers are evenly distributed in the house. Drinker requirements for breeding birds are typically 8–10 birds per nipple drinker or 1.5–2.5 cm per bird if bell or trough drinkers are used (EFSA AHAW Panel, 2010). In cages for laying hens, it is recommended that there is access to at least two drinkers in case of failure in a drinking nipple and one can assume that that this is a risk also for broiler breeders kept in cages. Some farmers restrict access to water to prevent over drinking and to minimise problems with wet litter giving access around and for a period of time after feeding (de Jong and Emous, 2017). Restricting access to water would presumably increase the competition for drinking when water becomes available, but this has not been investigated.

3.5.2.7. Enrichment

Environmental enrichment should 'enhance animal welfare by providing them *(i.e., the animals)* sensory and motor stimulation, through structures and resources that facilitate the expression of species-specific behaviour and promote psychological well-being through physical exercise, manipulative activities, and cognitive challenges according to species-specific characteristics' (National Research Council, 2011). Broiler barns are mostly barren: a littered area with feeder and drinker lines. Environmental enrichment for broilers should stimulate them to explore and can consist of different structures including plenty of dry litter, raised platforms, straw bales and alike, covered verandas, outdoor access, and may enhance animal welfare in different ways (Riber et al., 2018; Bach et al., 2019). Particularly, in broilers, enrichment items should increase their activity to prevent locomotory disorders (Kaukonen et al., 2017b). Indeed, raised platforms can reduce lameness (Phibbs et al., 2021) and FPD (Ohara et al., 2015) although de Jong et al. (2021) found no effect. Broilers prefer platforms over perches (Kaukonen et al., 2017b). Broiler breeders and breeder pullets, use perches integrated in raised tiers of aviaries (Gebhardt-Henrich et al., 2018; Vasdal et al., 2022b). However, enrichment items can also increase the risk of health issues and must be chosen wisely to benefit the particular category of bird. Chopped straw and straw bales, e.g. can lead to an increase of FPD due to bacterial infections (Tahamtani et al., 2020). Too much enrichment leading to too much exercise may increase the risk of inflammation, e.g. wooden breasts (Sihvo et al., 2014; Velleman and Clark, 2015). In contrast, vertical panels do not cause wooden breasts (Pedersen et al., 2020). Broiler breeders with perches have more keel bone damage than broiler breeders without perches (Gebhardt-Henrich et al., 2017b). Slower-growing broilers use and benefit from enrichment possibly more than fast-growing hybrids (de Jong et al., 2021).

An unequal distribution of broilers in the barn can lead to bad litter quality at certain places and locally high densities. A more even distribution of broilers may be achieved by providing barrier perches, which also have the benefit of decreasing aggression (Ventura et al., 2012).

3.6. Impact of genetics on broiler welfare

A tremendous increase in growth rate has been achieved in commercial broiler lines starting in the 1960s (Zuidhof et al., 2014), which is mainly due to genetics rather than diet or management improvements (Havenstein et al., 2003). Despite relatively small differences in the weight of hatchlings, feed intake, growth rate, and feed efficiency have been increased in the modern broiler lines. This led to an unproportional increase of size of the breast muscle to an extent that the conformation (gestalt) of the body of the broiler has changed profoundly and the broiler chicken has been called a novel *morphotype* (Bennett et al., 2018). Besides the intended beneficial changes in terms of productivity, the enhanced growth rate has led to various WCs in the broiler and the breeders (for a review see Hartcher and Lum (2020)).

Welfare consequences directly linked to the increase in growth rate and high body weight are locomotory, musculoskeletal disorders, and cardiovascular diseases, leading to an inability to perform exploratory or foraging behaviour and may cause mortality. High body weight and the disproportionately high weight of the breast muscle led to leg weakness and lameness manifested as poor gait scores and resulting inactivity. The broilers spend most of the time sitting and lying on the litter and are therefore prone to develop contact dermatitis like breast burns, and hock burn. Even worse, broilers with locomotory problems may stay near the feeder instead of moving to the drinker, and as a result they dehydrate and some of them may even die from dehydration. Fast growth has been linked to bacterial chondronecrosis with osteomyelitis, which causes severe locomotory problems and is a significant cause of culls and mortality (Wijesurendra et al., 2017). In addition, tibial dyschondroplasia, and valgus/varus deformities contribute to locomotory problems. All these ailments have a genetic basis and the incorporation of health and welfare traits in the selection program of the breeding companies has decreased but not eliminated the occurrence of those locomotory problems (Tahamtani et al., 2018a).

The fast-growing broiler is normally slaughtered at around 37 days at a body weight of around 2–2.5 kg, well before the animal reaches sexual maturity. Growth rate has to be reduced significantly in the breeder generations to avoid health problems in reproducing adult due to tendency for obesity. This is achieved by severe feed restriction leading to hunger in breeders (Decuypere et al., 2010). *Ad libitum* fed broilers beyond slaughter age become obese, develop heart and leg problems and, in case they survive until reaching sexual maturity, have reduced fertility (Hocking, 1990; Hocking et al., 1996; Hocking and Bernard, 1997). Welfare consequences in the breeder generations which are directly linked to the increase in growth rate and the need for severe feed restriction include 'prolonged hunger' and 'prolonged thirst'. The latter is because hungry birds may display polydipsia and, as a result, the water supply is shut off at certain times (see Section 3.4.2.8 Welfare consequence 'Prolonged thirst' and related ABMs in the Scientific Opinion).

Besides the fast-growing hybrids that can gain above 100 g per day (e.g. *Arbor Acres Plus* males (Aviagen, 2022)), hybrids with different growth rates are bred and marketed by the breeding companies, e.g. *Rowan Ranger Classic* with a weight gain around 50 g per day (Aviagen, 2018c) and, as an example of an even slower-growing hybrid, *Sasso* broilers reach their slaughtering age of 2.2–2.4 kg in 88 days. Sasso broilers are sold for small scale and organic farmers with access to free range (Sasso, 2020). As culling of male chicks has been banned in some European countries, males of dual-purpose hybrids (animals bred for meat and egg production) are a good alternative to slower-growing broilers. After 63 days, a slaughter weight of 1.92 kg is reached. However, the breast muscle is rather small which leads to a slender shape of the broiler (Aviforum, 2015). In general, hybrids with a weight gain above 60 g per day are considered fast-growing, a maximum weight gain of 50 g per day as intermediate, and a maximum growth rate of 45 g per day as slower-growing broilers (de Jong et al., 2022).

In the paper by Vissers et al. (2019) with some slower-growing hybrids kept under reduced stocking densities, production costs were only slightly increased whereas animal welfare was considerably improved. As an example, the slower-growing hybrid *Hubbard JA757* is more active and has better gait scores, better plumage, higher breast cleanliness, and less hock burn than the conventional fast-growing hybrids. At the same time, this slower-growing hybrid shows more locomotion, foraging, and comfort behaviours (Dixon, 2020). The same results, namely better health and more positive behaviour was found in two broiler hybrids gaining less than 50 g per day compared with fast-growing hybrids (Rayner et al., 2020). More positive behaviour such as locomotion, comfort and foraging behaviour are shown by the slower-growing hybrid *Ranger Classic* that uses the enrichment (straw bales) better than the fast-growing hybrid *Ross 308*. *Ranger Classic* birds are also less fearful than *Ross 308* (van der Eijk et al., 2022a). It has to be noted, that animal welfare is the better the more slowly the hybrid is growing. Thus, hybrids growing more slowly than *Rowan Ranger* with an intermediate growth rate have even better welfare especially at higher ages. (Wilhelmsson et al., 2019).

Without doubt, other factors besides growth rate, like the health of the birds, management, and housing, influence animal welfare conditions leading to variation between flocks within hybrids. Some of these factors interact, such as slower-growing hybrids in lower stocking densities and provided with enrichment achieve on average higher welfare scores than the fast-growing hybrids (de Jong et al., 2022).

In addition to improving broiler' welfare, broiler breeders benefit from a genotype for slower daily weight gain. The necessary feed restriction especially during rearing is more severe and of longer duration for fast-growing than for slower-growing hybrids (Puterflam et al., 2006; Arrazola and Torrey, 2021). This leads to higher stress levels and welfare problems in broiler breeders of fast-growing compared with slower-growing hybrids (Arrazola and Torrey, 2021). Dwarfed females of slower-growing hybrids like Sasso or Hubbard dwarfed broiler for Label production do not need to be feed restricted during egg production, at all (Puterflam et al., 2006).

The feasibility of transitioning to higher welfare standards by using slower-growing genetics of broilers as one of the measures has been successfully demonstrated by the Dutch market (Saatkamp et al., 2019). In conclusion, the health and welfare status of broilers mainly depends on the genetics. Welfare in broilers and their breeders must be improved both by emphasising these traits in the selection index, as well as using hybrids with lower growth rates.

Genetic selection impacts many highly relevant welfare consequences described in the present opinion, therefore ABMs related to these welfare consequences as well as iceberg indicators can be used to assess the status of the birds related to genetic selection. These ABMs are mainly related to 'locomotory disorders', 'inability to perform exploratory and foraging behaviour' and 'inability to perform comfort behaviour'. Related ABMs for broilers and breeders are: 'dustbathing' (see Section 3.4.2.4 for a description of the ABM), 'walking impairment' (see Section 3.4.2.21), 'locomotory behaviour' (see 3.4.2.14), foraging behaviour ('walking, scratching and pecking', see 3.4.2.5), 'plumage damage' (see Section 3.4.2.21). For breeders: 'wounds' (mutilations are included, see Section 3.4.2.21), 'stereotypic behaviour' (see Section 3.4.2.21).

3.7. Feed restriction & prolonged hunger in broiler breeders (specific ToR 3a)

3.7.1. Introduction

Broiler breeders are feed restricted to different degrees depending on their genotypic growth rate to avoid animal health and welfare problems due to their tendency to obesity. They are also restricted differently during rearing and the production period. EFSA identified mitigative measures relating to 'different feed restriction practices' in this context.

The different 'practices' focus on different elements: (i) amount of protein intake per day, (ii) amount of energy intake per day, (iii) amount of fibre per day (soluble and insoluble), (iv) feeding program (i.e. number of meals per week and meals per day) and (v) addition of appetite suppressants.

3.7.2. Feed restriction of broiler breeders

3.7.2.1. Description of feed restriction in broiler breeders

In the past decades, broilers have been selected for fast growth and high feed efficiency (Zuidhof et al., 2014). Since the parental lines have similar genetics as broilers, but are kept until and beyond sexual maturity, all broiler breeders experience some level of feed restriction to reduce their growth rate (Siegel and Wolford, 2003). The higher the growth rate of the broilers, the higher the growth rate of the parental lines, the higher the feed restriction applied to breeders. This feed restriction is most severe during the rearing period, and more severe for the very fast-growing hybrids than for the slower-growing hybrids (Puterflam et al., 2006; Dixon, 2020; Arrazola and Torrey, 2021). Currently, feed restriction is not solely practiced ensuring health and production but may also be partly done to reduce production costs.

The studies cited below were conducted on fast-growing hybrids unless stated otherwise. The intention of reducing the growth rate is to reduce health and welfare problems that are brought on by the selection for fast growth rates, especially lameness and mortality due to being overweight (Decuypere et al., 2010). Additionally, non-feed restricted and therefore obese birds have an altered ovarian function resulting in poor fertility during the egg production phase (Hocking et al., 2002). Therefore, with the hybrids currently used, severe feed restriction is necessary for the health of broiler breeders of fast-growing hybrids, especially during rearing. Slower-growing hybrids also need to be feed restricted, though to a lesser extent. This conflict and the difficulty in reconciling good health and reproduction without applying some form of feed restriction, causing birds to experience prolonged hunger (Dixon et al., 2014), has been called the 'broiler breeder paradox' (Decuypere et al., 2010).

During feed restriction, the challenge is to ensure that all animals have access to feed. When the feed quantity available at each meal is small, there is a risk that smaller, weaker or less dominant animals do not access feed. If food portions are large enough, smaller individuals have the opportunity to obtain feed after the more dominant animals have eaten. This can be achieved in several ways:

1) The (restricted) amount is fed in only 1–2 daily feeding events. The number of feeding events can differ according to the age.
2) A larger feed portion than if fed daily is allocated on some days and no feed is offered the following day (skip a day feeding). Various schedules of days per week with and without feed exist, e.g. four days per week with feeding and three non-consecutive days per week without feeding. In some cases, non-digestive feeds like soybean hulls are offered on the days off. Some countries demand daily feeding which prohibits this so-called skip a day feeding regimen.

3.7.2.2. Welfare consequence linked to feed restriction

All broiler breeders have to be feed restricted during growth to control weight gain (Decuypere et al., 2010; Riber et al., 2017), causing 'prolonged hunger' as described in Section 3.4.2.7.

When comparing fast- and slower-growing hybrids, the fast-growing hybrids need to be feed restricted more severely and experience a greater level of hunger than slow-growing hybrids and dwarfed females (Puterflam et al., 2006; Arrazola and Torrey, 2021). Thus, better welfare is to be expected in slow-growing hybrids (Dixon, 2020). Some individuals within a flock grow less well and remain smaller than the mean which could be a coping mechanism for feed restriction and convey higher welfare than bigger sized birds (Lindholm et al., 2015), since less feed is required. Some slower growing hybrids consist of dwarfed females and normal-sized males. In those hybrids the dwarfed females likewise benefit from their small size and lower feed restriction compared to normal-sized females. In general, feed restriction is relaxed during egg production and slower-growing hybrids especially when females are dwarfed may not be feed restricted during this period at all.

3.7.2.3. ABMs to measure hunger due to feed restriction in breeders

Feed restriction leads to a high motivation to feed and to stereotypic behaviour patterns like pacing (see Section 3.4.2.21), injurious pecking (see Section 3.4.2.21), spot, object pecking (Hocking et al., 2001, 2002, 2004; Merlet et al., 2005; Dixon et al., 2022) including pecking at empty feed troughs or feather pecking, plumage damage (Girard et al., 2017a) and polydipsia (Section 3.4.2.7) leading either to watery faeces causing poor litter condition (Lintern-Moore, 1972; Savory and

Mann, 1997; Li et al., 2018). Furthermore, feed restricted broiler breeders show elevated levels of stress hormones and reduced density of new neurons in the hippocampal regions of the brain (Robertson et al., 2017), which may be the reason for the observed reduced learning capacity in broiler breeder females (Buckley et al., 2011). Several physiological parameters are affected in feed restricted birds indicative of hunger. Feed restricted birds have higher concentrations of plasma non-esterified fatty acids (NEFA) and also have mRNA expression of the neuropeptides agouti-related protein (AGRP) and Neuropeptide Y (NPY) as indicators of hunger with lower expression of the anorectic gene Pro-opiomelanocortin (POMC) in the basal hypothalamus than *ad libitum* fed birds (Dixon et al., 2022).

3.7.2.4. Description of the main feed regimens currently applied to reduce the hunger due to feed restriction

Different measures have been developed to attempt to decrease the feeling of hunger in the birds, while continuing to apply a feed restriction.

Increasing the time feeding

A strategy for decreasing the feeling of hunger that has been investigated in multiple studies is to increase the amount of time that broilers dedicate to eat the feed by two ways: (i) composition of the feed: providing a diet with a lower energy level, providing more insoluble fibre and lower level of protein, and/or (ii) the presentation of the feed: scatter feeding vs trough feeding and mashed feed vs pellets. Scatter (spin) feeding instead of providing the feed in troughs requires the birds to spend more time foraging and has been shown to reduce object pecking, i.e. stereotypic behaviour, but not other measures of hunger (de Jong et al., 2005). If feed is provided in feeders, mashed feed instead of pelleted feed can be provided, which takes more time to eat.

Decrease appetite

Calcium proprionate in the feed has been used as an appetite suppressant in North America with the intention to reduce the prolonged hunger induced by feed restriction. However, evidence from studies examining appetite suppressants is mixed. Calcium proprionate can induce negative affective states in broiler breeders due to a sickness feeling as shown by an increasing avoidance of this substance compared with a placebo (Arrazola et al., 2019a).

Relaxing feed restriction by allowing higher growth rate

Hunger can be alleviated by relaxing feed restriction while adopting a higher growth trajectory without negative consequences on health and reproduction (Afrouziyeh et al., 2021).

A 10% higher growth trajectory than the one actually allowed led to less feeding motivation (Dixon et al., 2014; de los Mozos et al., 2017) and, additionally, better production (Afrouziyeh et al., 2021). It has already been shown that increased feed provision in the parents is beneficial for the growth rates and immune functions of the broiler offspring through transgenerational effects (Bowling et al., 2018). There are variations in the diet recommendations for the same hybrids between countries demonstrating that there are alternatives concerning the extent of feed restriction. Therefore, the level of feed restriction has to be reconsidered and relaxed.

Slower-growing animals should be used, so that feed restriction is not needed or less severe.

Skip a day alone or associated with other methods

Results from studies on the effects on welfare of alternative non-daily feeding strategies (skip a day (SAD)) aiming at mitigating hunger vary.

The stress hormone corticosterone is generally elevated during fasting (De Beer et al., 2008). Consequently, birds on SAD feeding had higher corticosterone levels than birds on daily feeding schedule (Mench, 1991). However, plasma corticosterone might be influenced by the metabolic rate and an elevated level does therefore not qualify as a good indicator of stress (de Jong et al., 2002).

SAD feeding is done mainly in North America and in some EU countries whereas other EU countries like NL do not allow it (E. van Emous, personal communication, 9 November 2022). Although some studies provide inconclusive results concerning the implications of SAD feeding for welfare, e.g. Lindholm et al. (2018), shows new evidence that SAD feeding is detrimental to the health and production of the birds. Thus, SAD feeding programs are under discussion in countries that use it. Likewise, SAD feeding is detrimental to production due to changes of the metabolism and body composition by lowering the efficiency (de Beer and Coon, 2007). Production parameters did not differ between SAD fed and daily fed breeder pullets in another study, but the innate and the adaptive immune systems were more active in the daily fed birds compared with the SAD birds (Montiel, 2016). Arrazola et al. (2019a) found that the SAD feeding, and the age-adjusted frequency of feeding events induced less hunger than the control diet (standard diet fed daily) during rearing of broiler breeders. All modified feeding strategies in this study later impacted egg production (Arrazola et al., 2019b). However, non-daily feeding led to slower growth than expected so management strategies would need to be optimised. Birds with the SAD feeding had a higher feeding motivation (presumably a higher hunger level) at the end of lay during production (Arrazola et al., 2019b). Additionally, Arrazola et al. (2020a, b) showed that SAD feeding and the inclusion of soybean hulls (qualitative change in the feed, see below) can reduce feeding motivation and the development of fault bars, indicating stress, in the feathers during rearing. Lindholm et al. (2018) highlighted that the provision of feed must be predictable, and it is unclear if birds learn the skip a day feeding schedule. The provision of soybean hulls on the days off led to more similar behaviour on days with and without feed, but no effect was found on corticosterone levels (Aranibar et al., 2020). Morrissey et al. (2014) did not find a decrease of hunger when applying skip a day feeding programs, but a combination of skip a day feeding with provision of soybean hulls and with appetite suppressants seem to decrease hunger, but the evidence was weak.

Qualitative change in the feed

Compared with SAD feeding, feeding a diet with high fibre content daily increases the uniformity in body weight during rearing, advances the age at the first egg, leads to heavier eggs, and improves egg shell quality (Sweeney et al., 2022). There has been a considerable number of studies investigating the extent to which different methods of qualitative feed restriction (e.g. by adding fibre or other non-nutritive substances to the diet) as compared to the standard quantitative feed restriction affect hunger in broiler breeder females (Riber et al., 2021b). Adding roughage to the diet improved the welfare of the broiler breeders (Tahamtani and Riber, 2020). Likewise, de los Mozos et al. (2017) claimed that diluting the feed reduced the feeling of hunger. In contrast to insoluble fibers with favourable impacts on welfare, soluble fibres can lead to feeling of sickness, reduced resting comfort (Tahamtani and Riber, 2020), and general discomfort in birds, as well as watery faeces and downgraded litter leading to additional negative welfare consequences, including soft tissue lesions linked to contact dermatitis (Nielsen et al., 2011; Moradi et al., 2013; Tahamtani and Riber, 2020).

Litter moisture was also elevated with a diluted diet consisting of 40% soybean hulls and 1–5% calcium propionate but this diet decreased hunger. However, the birds with the diluted diet had a slower age-related decrease in laying rate during egg production (Arrazola et al., 2019a).

Li et al. (2018) showed that a reduction in protein level increased litter quality by reducing water intake but may also reduce feather quality and cause frustration due to hunger. The 25% protein reduction applied by Li et al. (2018) might have been too severe because an age-adjusted reduction between 6.18 and 24% led to higher welfare as seen by a reduction of stereotypic object pecking although corticosterone levels were not altered (van Emous et al., 2014).

Even if some differences in behaviour are observed, which may suggest that qualitative feed restriction may improve bird welfare, when compared to the standard commercial practice, birds still seem to experience a considerable level of hunger when being qualitatively feed restricted.

Adapting feed intake individually

PLF (Precision Livestock Farming) methods enabling to distribute a certain amount of feed to individuals based on their individual physiological needs have become available but are rarely used in poultry so far, and only under experimental conditions. Besides the positive result that PLF feeding seemed to reduce, although not eliminate, feeding motivation compared with skip a day (Girard et al., 2017a), PLF fed birds were more aggressive than SAD fed birds (Girard et al., 2017b). In the case of PLF, feed is available but not for all individuals which might cause even more frustration in the birds denied feed. The presence of feed stimuli might be of high importance for the bird experiencing hunger, but more research is needed on how this can be avoided in case of PLF and in general. Another problem arises when birds are marked during a learning phase because dye marks can trigger aggression (Zukiwsky et al., 2020). At this time, it is not clear how the prototype can be applied to large commercial flocks. However, PLF is a rapidly developing field and new developments have to be followed (Yang et al., 2021).

3.8. Mutilations in broiler breeders (Specific ToR 3b)

3.8.1. Mutilations in broiler breeders leading to soft tissue lesions and integument damage

Another issue common to all broiler breeders irrespective of housing system is soft tissue lesions, resulting from mutilations. In general terms, mutilation can be defined as an act or instance of destroying, removing or severely damaging a limb or other sensitive body part of a person or animal (Merriam-Webster, online). In broiler breeders, mutilations may include beak trimming in both males and females, removal of one or more claws or toes in males and dubbing of the comb in the males (Fiks-van Niekerk and de Jong, 2007). There are ongoing discussions about mutilations within the EU. Some countries have banned all forms of mutilation. Other countries are phasing them out and there is variation between countries in what is allowed or not, as well as variations between breeding companies.

Beak trimming is banned in some countries, but when it is used, the intention is to reduce feather pecking damage in both sexes and damage in males because of fighting. It may also reduce the damage to the neck of the females during mating (Gentle and McKeegan, 2007). Beak trimming is not as common in broiler breeders as in layer breeders, although in some countries all birds are regularly beak trimmed. As in layers, where most of the research has been carried out, the procedure has been shown to be painful, resulting in sensory loss (Gentle and McKeegan, 2007; Gentle, 2011). The amount of pain will vary with the method used and how much of the beak is removed (see van Fiks-van Niekerk and de Jong, 2007 for an overview). In addition to the acute pain, it is associated with chronic pain although the extent of the pain varies according to the exact procedure used.

The most commonly used method for beak trimming in the EU is the infrared procedure performed at the hatchery. The infrared energy is directed at the beak tip until it penetrates the underlying tissues. The beak tip softens in the days after treatment and the sharp beak tip is either eroded or drops off, with only limited regrowth as the underlying germ-layer tissue is also destroyed during the trimming process (Glatz and Underwood, 2020). The infrared method is more precise than hot blade trimming with fewer birds showing beak shaped abnormalities (Carruthers et al., 2012). There are long-term consequences of beak trimming, which is the intention, since beak trimming is used to reduce damage when a bird pecks at the feathers or at the skin of another bird. However, there are likely to be welfare consequences for any behaviour involving the beak, e.g. exploratory, feeding behaviour and preening (Marchant-Forde et al., 2008; Angevaare et al., 2012; Hartcher et al., 2015). There is no reason to believe that the welfare consequences of beak trimming for broiler breeders are different to those for birds of laying hybrids (EFSA AHAW Panel, 2023).

There is already an ongoing debate about banning beak trimming in laying hens, which are generally considered to have greater problems with injurious pecking than broiler breeders. The justification to continue to beak trim broiler breeders is therefore weak.

Toe clipping and de-spurring are used to reduce the risk of injury to females by males during mating. It is the outermost joint of the toe pointing backwards (digit I, hallux) that is removed and occasionally also digit II (Riber, 2017). This joint removal has also been shown to cause pain immediately following amputation, and in the period afterwards, since neuromas were observed 60 days later (Gentle and Hunter, 1988). Further evidence of pain associated with this procedure is from turkeys. Indeed (Fournier et al., 2015) found changes in behaviour through day 5 post amputation in turkeys. Besides acute and chronic pain, these mutilations to the feet of birds could cause problems with balance and so with behaviours affected by this, e.g. scratching, walking, perching. Some companies are testing stopping any form of mutilations to the feet of broiler breeder males.

The relatively smaller comb size in modern broiler breeders means that comb trimming (dubbing) is no longer routine practice in the EU.

3.8.2. ABMs

The simplest measure is to examine the bird itself to determine whether or not it has been mutilated in any way. Mutilations to broiler breeders, and so relevant to this specific welfare consequence, are beak trimming and clipping of toes and claws. Changes in beak structure have been reported for infrared trimmed birds but at a lower frequency than for hot blade trimmed birds

(Carruthers et al., 2012), thus any changes in beak structure can be an indicator, although these are rare. Such information can be combined with information on the procedure used, linked to experimental work, to estimate the level of pain that might be involved, or that the bird may still be experiencing.

Indicators of pain include 'distress calls' and 'resistance to handling' and 'escape attempts' at the time of the event, followed by deviations from the expected growth rate indicated by impaired growth rate relative to other birds and changes in the time budget of the bird after the mutilation. The behaviours affected will depend on the type of mutilation. Beak trimming will affect beak related behaviours (pecking as part of foraging behaviour and preening) whereas toe clipping will affect walking and scratching as part of foraging and exploratory behaviour. Later effects may also be seen as reduced plumage damage on the neck of females when mated by beak trimmed male. Since all mutilations involve an extra handling procedure for chicks at the hatchery, ABMs related to this are also relevant, although the most likely are 'vocalisations' and 'escape attempts', one may also imagine that in the case of inappropriate handling there may also be dislocation and broken bones.

For ABM resistance to handling see Section 3.4.2.10, for ABM 'escape attempts (breeders)' see Section 3.4.2.10, for ABM 'impaired growth rate' see Section 3.4.2.7, for ABM 'preening (breeders)' see Section 3.4.2.4, for ABM 'walking, scratching and pecking' as part of foraging and exploratory behaviour (breeders) see Section 3.4.2.5.

3.8.3. Hazards

Performing the mutilation is the hazard per se. More specific hazards relate to the method used to carry out the mutilation, i.e. whether it involves any form of cauterisation or not, and the skill of the person performing the mutilation. For example, the way the chick is handled around the procedure, and especially immediately afterwards, may affect the speed of recovery (Adcock, 2021). Comparisons of methods of beak trimming suggest infrared trimming is associated with fewest welfare consequences, compared to other methods. There seems to be little scientific work comparing different methods of toe trimming.

3.8.4. Preventive measures

Since the mutilations are used to reduce the risk of damage resulting from abnormal behaviours, such as injurious pecking, or resulting from excessive aggression of males to females, or between males, the most direct method of prevention is to reduce the risk of these abnormal behaviours occurring in the first instance. This can be by genetic selection against them, or by rearing birds and housing them as adults under conditions that reduce the risk of them developing. For example, there is a considerable amount of literature on the importance of rearing condition on injurious pecking and the importance of access to appropriate foraging material and providing enrichment (See Nicol (2019) for review). There are differences in aggression associated with mating between broiler breeder lines. In relation to broiler breeders, potential preventive and corrective measures are to decrease difference of sexual maturity between males and females (de Jong and Guemene, 2011) and to have an appropriate ratio of males to females (Végi et al., 2013) wich is no more than 1/10.

3.8.5. Corrective and mitigative measures

It might be possible to provide an analgesic around the time of the mutilation to reduce the pain associated with the procedure. Such requirements are already in place in some countries for other mutilations such as castration, disbudding and tail docking. In this case, there should be a training requirement for the person performing the procedure to ensure it is carried out correctly.

3.9. The welfare of broiler breeders and the risks associated with housing in (individual) cages (specific ToR 3a)

Breeding companies keep some of their broiler breeders in unfurnished individual cages in order to measure traits of individuals and control breeding. Chickens are social animals, so isolation stress due to being housed alone was considered a severe welfare consequence for birds in individual cages. As these cages are small and barren, the welfare consequences 'inability to perform comfort behaviour', 'inability to perform exploratory and foraging behaviour', 'restriction of movement', and 'resting problems', because of missing perches, litter, and nestboxes (for females), were also considered highly relevant for this housing system. In addition, frequent handling, e.g. during matings leading to handling stress and injuries from the wire floor and cage boundaries, leading to soft tissue lesions and integument damage which are considered highly relevant welfare consequences. As it will be detailed below, the basic needs of chickens of social partners, space, litter, perches, and nestboxes (for females) are denied in this housing system leading to multiple WCs with their associated ABMs.

Social animals like chickens experience isolation stress when housed singly and are consequently prone to frustration and develop stereotypic behaviour such as excessively frequent preening of part of the plumage leading to feather damage, e.g. at the breast (Wood-Gush and Vestergaard, 1989). Besides the ABM feather damage, the ABMs 'distress calls' and 'escape attempts' may be exhibited by singly housed birds.

Housing chickens in (esp. in single and barren) cages also means that space is very limited and essential resources like litter, perches, and nest boxes are not provided. This elicits multiple welfare consequences. The natural behaviour of chickens, namely exploring and foraging while scratching in the litter, dustbathing in loose material, selecting dark secluded places when laying their eggs, and finally perching at an elevated location during sleep is incompatible with this housing system.

3.9.1. ABMs

In a single cage, a chicken is extremely restricted in the possibility to move (see section 3.4.2.14). The lack of movement may lead to bone and muscle weakness, because the muscle deposition is impaired and bones have a lower mineral content when chickens are unable to perch (Yan et al., 2014). The restriction of movement also means that the bird is unable to explore and forage in the species-specific way of walking, scratching, and pecking the ground (see section 3.4.2.5). Chickens are highly motivated to perform this behaviour and if this is impossible the development of stereotypic behaviour like pacing as an indication of frustration and poor welfare may result. The wire floor without loose substrate prevents the proper way of foraging, which involves scratching. 'Inability to perform exploratory and foraging behaviour' is especially severe in broiler breeders because they are inclined to show elevated rates of this behaviour due to feed restriction. The absence of litter also prevents the birds from dustbathing, an important comfort behaviour and the limited floor area and height impedes wing flapping and wing and leg stretching (see section 3.4.2.4). This may lead to dirty plumage because dustbathing is impossible.

Hens are highly motivated to search for appropriate nest sites to lay their eggs, i.e. a secluded, place with appropriate flooring. There is no such place in single barren cage so hens are frustrated daily and are likely to show stereotypic behaviour like pacing, or displacement behaviour like preening (Wood-Gush, 1972).

All chickens including broiler breeders (Gebhardt-Henrich et al., 2017b) are highly motivated to use aerial structures like perches, especially at night (Olsson and Keeling, 2000). The initial reason for perching in wild birds was the prevention of predation. Although resting birds cannot be disturbed by other animals when housed singly, resting problems are experienced by these birds because perching is a behavioural need even without the danger of predation. Thus, broiler breeders without access to perches were shown to be more fearful, meaning they remained longer in tonic immobility than broiler breeders with access to perches (Brake et al., 1994).

Singly housed breeders have to be mated by manual transfer of semen more often than once a week. This necessitates the handling of both males and females which elicits handling stress (de Jong and Guemene, 2011). Birds may show they are scared by attempting to escape during handling and struggle as resistance to handling. The severity of this WC will depend on the calmness and carefulness of the staff, so training of the staff on good handling practices will prevent the handling stress.

The wire floor may lead to damage of the footpads and toes can get trapped in badly designed wire constructions leading to soft tissue lesions and integument damage. Furthermore, due to the small size of the individual cages, feathers are in constant contact with the wire and may become ruffled and broken.

3.9.2. Preventive and Mitigation measures

In conclusion, keeping chickens in single cages leads to severe welfare consequences that cannot be prevented in this housing system. The severity of some of the welfare consequences may be mitigated by enlarging the space and adding furnishings like perches and nest boxes. However, even in this case, the isolation from other birds and the inability to perform essential behaviours that require litter material lead to stress and frustration. It is recommended that (single) cages are not used.

3.10. The welfare of fast-growing chickens in barns and the risks associated with access to feed and water (Specific ToR1b)

3.10.1. Access to feed and water for day-old chickens

Hatchery-hatched chickens may experience a delay in first feed and water access of typically 24–48 h (until they are placed in the barn), which is caused by the hatching moment in relation to pulling, handling of the chickens at the hatchery and transportation (see Section 3.3.1). A deprivation time of on average 48 h (range 36–60 h) is a hazard for 'prolonged thirst' and 'prolonged hunger' (Section 3.11).

Prolonged thirst and prolonged hunger in day-old chicks can be prevented by providing feed and water immediately post-hatch. There are commercially available systems that provide feed and water or semi-moist feed in the hatchery (see Section 3.3.1), preventing that chicks are deprived from feed and water in the first days-post hatch. With these systems, chicks still have to be transported to the farm. Feed and water are usually only provided during long-distance air transport (EFSA AHAW Panel, 2022a).

Alternatively, prolonged thirst and hunger in day-old chicks can be prevented by applying on-farm hatching where chickens have access to feed and water immediately after hatching in the barn (see Section 3.3.2 for description of the various commercially applied systems).

When chickens hatch in the hatchery and thereafter arrive in the barn, it is important that they find the feed and water quickly as especially early hatched chickens may have experienced a rather long duration of feed and water deprivation. Chickens should be placed as quickly as possible after arrival (Gussem et al., 2015).

First, the chickens should be provided with the appropriate air and floor temperature (air temperature of 30–35°C with whole house heating and floor temperature of 28–30°C, see Section 3.5.1.5) to stimulate the chickens to search for feed and water. Chickens experiencing cold stress will not go to feed and drink (see Section 3.5.1.5), which will prolong the duration of hunger and thirst. Similarly, chickens that have experienced heat stress will be less able to find feed and water (Gussem et al., 2015).

Young chicks learn to drink by pecking to everything that shines (pools, dew drops). Also, social facilitation plays a role, if young chicks do see other chicks drinking, they will go to the water source and copy the behaviour (Bestman and Keppler, 2005). When using drinking nipples, drinking can be stimulated by tapping or shaking the nipples so that each nipple has a visible drop of water which is attractive to the day-old chickens (de Jong et al., 2016c). Nipple lines should be low during the first days so that these are easily accessible by the chickens (Gussem et al., 2015). Water temperature also affects water consumption (18–21°C has been suggested as the ideal temperature). During the first 3 days additional mini-drinkers and trays can be provided to stimulate drinking; these can be gradually removed after the chickens learned to drink from the nipples or bell drinkers (Gussem et al., 2015; Aviagen, 2018a).

Upon arrival of the chicks, feed should be spread over chick paper on the floor or on flat trays under the feeders to promote eating. For young chickens this should be crumbled feed or small pellets. Upon placements chickens should be placed on the paper so that the feed is immediately found (Gussem et al., 2015; Aviagen, 2018a). Chick paper or additional trays should be removed when the chickens eat from the main feeders, which is around 4–5 days of age.

Farmers should check the chickens for eating and drinking, starting from 2 h after placement, then regularly every 3–4 h during the first day and less frequently the next day (4, 8, 12, 24 and 48 h after placement, (Aviagen, 2018a)). Crop fill can be used as indicator of feed consumption. It is advised to collect samples of 3–40 chickens from 3 to 4 different places in the house and assess the crop content. If chickens eat and drink properly, the crop should be filled, soft and rounded (Gussem et al., 2015; Aviagen, 2018a). In addition to crop fill, observations of eating and drinking behaviour and distribution of birds are indicators that chickens have started eating and drinking and do have the appropriate environmental conditions (see Section 3.5.1.5).

'Body weight loss', 'lethargy' and 'mortality' have been defined as ABMs for 'prolonged hunger' and 'prolonged thirst' in day-old chickens (see Section 3.4.2.21).

3.10.2. Access to feed and water during rearing

This relates to broiler chickens in all housing systems. Broiler chickens usually have (nearly) *ad libitum* access to feed and water during rearing. During the rearing period, the height of the drinkers and feeders is adjusted to the height of the chickens. Regarding drinkers, it is common practice to use drinking nipples (preferably with drip cups) and provide these at such a height that broiler chickens need to stretch their neck to obtain water from the nipple. If drinkers are too low, there is too much spillage with a risk for wet litter and contact dermatitis. Also bell drinkers, which are less common in commercial practice should be positioned in such a way that the chicken can make the characteristic drinking movements with their head and neck (Heidweiller and Zweers, 1992). Feeders and bell drinkers are usually positioned in such a way that the bottom of the feeder or bell drinker is at the height of the top of the breast (Aviagen, 2018a). The size of the smallest chickens in a flock will determine the height of feeders and drinkers, and the farmer will observe feeding and drinking behaviour to adjust the height of feeder and drinker lines. If some very small chickens are present in a flock ('runts') these will not be able to reach the feeders and drinkers with increasing height and will then suffer from prolonged hunger and thirst. Similarly, chickens unable to walk (gait score 4 and higher) will be unable to reach the feeders and drinkers and suffer from prolonged hunger and thirst (Weeks et al., 2000). As these are usually a small proportion of the flock, the farmer needs to pay attention to these chickens during the daily checks of the flock and, when no other alternative is possible, needs to cull the chickens using the appropriate method to prevent (further) suffering (EFSA AHAW Panel, 2019).

'Voluntary water consumption' and the 'pinch test' have been identified as ABMs for 'prolonged thirst' (Section 3.4.2.8) in broiler breeders and are also applicable to broilers. 'Body weight loss' has been identified as ABM for 'prolonged hunger' in day-old chickens (Section 3.4.2.21). 'Impaired growth rate' has been identified as ABM for 'prolonged hunger' in broiler breeders and is also applicable to broiler chickens (Section 3.4.2.7).

If older broilers are too small ('runts') or cannot walk (gait score of 4 or higher) these should be culled, using the appropriate method (as defined by EFSA AHAW Panel, 2019). Farmers need to check their flocks daily to identify these chickens.

3.11. Welfare of Day-Old-Chicks until they reach the rearing or breeding farms: hazards under hatchery conditions (specific ToR 4)

3.11.1. Introduction

Several welfare consequences are linked to the early life of broiler and broiler breeder chicks at the hatchery before they are loaded for transport. Among these are 'sensory under- and overstimulation', 'prolonged hunger', 'prolonged thirst', 'resting problems', 'cold stress' and 'handling stress'. The welfare consequences and the related ABMs, hazards and preventive/corrective measures are briefly described below, but see Sections 3.4.2.20, 3.4.2.7, 3.4.2.8, 3.4.2.15, 3.4.2.3, 3.4.2.10 for more details. One exception is 'cold stress', which has been left out in the current specific ToR, as it is included in the section dedicated to the temperature of the minimal enclosure (see Section 3.5.1.5).

3.11.2. Sensory under and/or overstimulation

The chicken embryos acquire the capacity to see, hear and smell at different developmental stages during incubation (Reed and Clark, 2011). Thus, already prior to hatching, the chicken embryo perceives stimuli from the surrounding environment. After hatching, the chicks may stay for up to 48 h in the hatchery, depending on the hatching window allowed.

During incubation, light is typically not provided, i.e. the chicken embryos/chicks, are kept in 24 h of darkness, which appears to affect welfare of the chickens short-term and long-term. It has been suggested that provision of light during incubation has a positive effect on stress coping in chickens (Zeman et al., 2004). Furthermore, provision of light during incubation has been demonstrated to reduce fearfulness and increase foraging behaviour at 3–6 weeks of age (Archer and Mench, 2017) and 5, 7 and 24 days of age (Dayioglu and Özkan, 2012), respectively. In layer chicks, light provided during the last 3 days of incubation, i.e. the period in the hatcher, has been shown to improve the young chicks' discriminative and spatial learning in feed-related tasks (Rogers et al., 2007; Rogers, 2008).

Another potential welfare issue is the level of noise during incubation. The motor and ventilation system create a constant background noise, which has been reported to be 70 dB (Tong et al., 2015b), likely varying depending on system. Excessive noise during incubation can influence social behaviour, fearfulness, cognition and stress reactivity of the chicks (Chaudhury et al., 2010; Kauser et al., 2011; Sanyal et al., 2013). It is a rather unexplored topic, but the nature of the noise, the sound pressure level and the pattern of noise are among the factors influencing the impact of the noise (Chaudhury et al., 2010; Kauser et al., 2011; Sanyal et al., 2013; Roy et al., 2014). The effects of noise demonstrated have mainly been short-term (e.g. Kauser et al., 2011; Rodenburg et al., 2017). There is a gap of knowledge in the scientific literature on the effects of early post-hatch exposure to excessive noise on the welfare of chicks.

3.11.2.1. ABMs

Suitable ABMs are limited but testing of 'fear response' (see Section 3.4.2.21) may be applied on day-old chicks while in the hatchery.

3.11.2.2. Hazards

During incubation, hazards are the lack of a diurnal light/dark schedule and a constant high background noise originating from the motor and ventilation system. Due to the divergent results and the complexity of sound as an influencing factor on welfare, many gaps of knowledge remain for which reason the exact hazards related to auditory stimuli during incubation remain unclear.

3.11.2.3. Preventive measures

Introducing a diurnal light/dark schedule of approximately 12 h/12 h (light/darkness) and avoiding loud arrhythmic noise during incubation seems to be beneficial to animal welfare (Chiandetti et al., 2005; Sanyal et al., 2013; Archer and Mench, 2017). With on-farm hatching, noise levels are likely much lower as compared to the hatchery.

3.11.2.4. Corrective and mitigative measures

Sudden loud noises should be stopped immediately.

3.11.3. Prolonged hunger and thirst

Traditionally, and by far the most common practice, broiler and broiler breeder chicks hatch in hatcheries after 21 days, 18 days of incubation followed by approximately 3 days in a hatching chamber. Hatchery chicks are exposed to a range of hatchery procedures involving handling. These include sorting chicks from eggshells, sorting second-grade chicks from first-grade chicks, vaccination (by injection and/or spray) and in some cases sexing. This is followed by crating in boxes, loading in trucks and transportation. Access to feed and water is typically delayed for 24–48 h, sometimes longer, after hatch in hatchery chicks (de Jong et al., 2016a).

Therefore, all broiler and broiler breeder chicks hatching in traditional hatchery systems experience prolonged hunger and thirst to some degree, and some of them will experience prolonged hunger and thirst for a duration that has been shown to impose negative effects on welfare (Xin and Lee, 1997; Fairchild et al., 2006; de Jong et al., 2017). Chicks hatch with a yolk sac that provides nutrition for maintenance and growth in the period immediate after hatching. However, the capability of the yolk sac to meet all nutritional requirements of the newly hatched chick, i.e. to compensate for lack of access to feed and water without any negative impact on long-term animal welfare, have been disputed (Willemsen et al., 2010a). Some studies find that early post-hatch feeding stimulates resorption of yolk, whereas others find the opposite result (reviewed in de Jong et al. (2017)). A meta-analysis of the effects of feed and water deprivation revealed negative long-term effects on mortality and performance starting after an average of 48 h (range: 36–60 h) of deprivation (de Jong et al., 2017). These results indicate that prolonged hunger and thirst have a long-term negative impact on animal welfare. Effects were also found on organ development and physiological indicators, but these appeared to be mainly short-term (de Jong et al., 2017). Furthermore, prolonged thirst may result in lethargy and prostration of the chicks (Borges et al., 2004).

3.11.3.1. ABMs

Body weight loss occurring between hatching and loading for transport may indicate prolonged hunger (de Jong et al., 2017) or dehydration due to prolonged thirst (Fairchild et al., 2006). Prolonged thirst may also result in lethargy and prostration (i.e. being unable to stand (Borges et al., 2004)). See Section 3.4.2.21 for ABM 'Body weight loss' and ABM 'Lethargy'.

3.11.3.2. Hazards

Hazards for prolonged hunger and thirst are post-hatch water and feed deprivation for a period of approximately 48 h (range 36–60 h) (Willemsen et al., 2010a; de Jong et al., 2017) and long hatch windows (van de Ven et al., 2011). In hatcheries applying an early feeding system, another hazard is disruption in water and food supply. Too high effective temperature during the waiting period in chick boxes is a hazard for prolonged thirst (Xin and Harmon, 1996; Maman et al., 2019).

3.11.3.3. Preventive measures

Providing water and feed or liquid feed (i.e. hydrogels) immediately post-hatch in the hatchery (Van der Pol et al., 2015; Souza da Silva et al., 2021) and applying on-farm hatching where the chicks have access to feed and water immediately post-hatch (van de Ven et al., 2009; Souza da Silva et al., 2021) prevent prolonged hunger and thirst. Reducing the duration of the hatch window (Bergoug et al., 2013a) and post-hatch handling and holding in the hatchery will reduce the time until access to water and feed on-farm (Careghi et al., 2005; Willemsen et al., 2010a). Increasing space allowance in the chick boxes, increasing ventilation and reducing environmental temperature to the thermocomfort zone of the chicks and providing water via gel while in the boxes will reduce the risk of overheating (effective temperature > 35°C) and otherwise exacerbate the negative welfare consequences of prolonged thirst (Maman et al., 2019). Several studies have shown that provision of hydrogels during the post-hatch holding period improves growth performance of broilers, poults and emus (Dibner et al., 1998; Noy and Sklan, 1999; Batal and Parsons, 2002; Mozdziak et al., 2002), but has no effect on mortality rates (Noy and Sklan, 1999; Batal and Parsons, 2002; Henderson et al., 2008; Lowman and Parkhurst, 2014; Özlü et al., 2022). However, a recent study showed no effects of provision of hydrogels in the chick boxes during the preplacement holding period on the yolk-free body mass or residual yolk sac of broilers at placement, the state of crop filling 3 h after placement in the barn or on the body weight gain and cumulative mortality after the first week (Özlü et al., 2022). No recordings were made of whether or to what extent the hydrogel was ingested by the chicks, complicating interpretations of the results. There is a lack of research on effects of hydrogels on other ABMs (e.g. affective states) than those related to production (e.g. body weight gain, mortality rates, crop filling) in relation to the prolonged hunger and thirst experienced. Early access to feed and water has been hypothesised to stimulate development of the gastrointestinal system (Willemsen et al., 2010a).

3.11.3.4. Corrective and mitigative measures

See Section 3.4.2.7 and 3.4.2.8. Although the first findings on the provision of feed and water during or right after hatching are positive, more research is needed to define the exact modality of early feed and water provision to day old chicks in the hatchery and during transport as well as the potential impact on chick's health and welfare.

3.11.4. Resting problems

When pulled from the hatcher, the chicks are exposed to light, which is often provided continuously up until the age of 3 days, except for the time spent in the waiting room, where often blue light at low light intensities is used, and under transport. In addition, the hatchery procedures that involve balancing on conveyor belts, drops from belt to belt or in boxes, vaccinations by spray or injections and other forms of handling by humans leave limited possibilities for the chicks to rest. Interestingly, a rebound in resting behaviour is not observed when hatchery-hatched chicks are placed on farm. Jessen et al. (2021a) reported hatchery-hatched chicks to rest less during the first 23 h after being placed on farm compared to chicks hatched on farm, which may be due to a higher stress level experienced by the hatchery chicks as well as an urgent need for feeding and drinking after being feed and water deprived since hatch.

3.11.4.1. ABMs

ABMs for assessing 'resting problems' at hatcheries are scarce and difficult to apply. While on the conveyor belt, it can be assumed that the chicks are prevented from resting. While in the boxes in the waiting room, the ABMs 'bird disturbance' and 'resting birds' may be considered (see Section 3.4.2.15), but it is likely difficult/impossible to observe the number of bird disturbances and resting chicks in the densely packed boxes and to do it without disturbing the chicks as the boxes are stacked.

3.11.4.2. Hazards

Among the hazards for resting problems are post-hatch handling and processing. The densely packed boxes used for transport is a hazard for resting problems as the limited space allowance likely enhance bird disturbances. Constant light at high light intensities is another hazard for resting problem.

3.11.4.3. Preventive measures

Resting problems may be prevented by on-farm hatching, where the handling and processing of chicks post-hatch are reduced or not even done (van de Ven et al., 2009; de Jong et al., 2019, 2020; Souza da Silva et al., 2021; Jessen et al., 2021a). Furthermore, space allowance is generally higher, which reduces the risk of bird disturbances. However, some farmers allow hatching to occur only in a limited part of the barn, which may reduce the level of benefits gained when applying on-farm hatching as a preventive measure against bird disturbances.

3.11.4.4. Corrective and mitigative measures

Dimming the light intensity during the holding period at the hatchery encourages synchronous resting, mitigating resting problems.

3.11.5. Handling stress

The hatchery procedures involve both mechanical and manual handling that may be experienced rough by the chicks depending on the speed of the belt, the height of the drops, the design of the system, the training of the staff, etc. (see Section 3.4.2.10). A study of layer chicks showed that the normal hatchery procedures are stressful to the chicks, having both short-term and long-term consequences on behaviour and stress reactivity (Hedlund et al., 2019).

3.11.5.1. ABMs

Suitable ABMs for assessing handling stress at the hatchery are 'chick righting time', i.e. the latency for a chick to right itself when placed on its back on a flat and stable surface (Knowles et al., 2004), and 'orientation (facing forward, backward, sideways) and posture (standing, sitting, lying) when on the belts' (Knowles et al., 2004; Giersberg et al., 2020). In addition, a range of fear tests may be used to assess the fear response to the handling (Giersberg et al., 2020). The prevalence of chicks with trauma (fatal or non-fatal) and 'chicks falling on the floor' indicate rough hatchery procedures and therefore are indicators of handling stress. See section 3.4.2.10 for more information on the ABMs.

3.11.5.2. Hazards

Hazards are changes in velocity (e.g. falling on another belt with a different speed) greater than 0.4 m/sec (Knowles et al., 2004), drop heights above 280 mm when switching from one belt to another or when dropping into a crate (Giersberg et al., 2021) and speeds of $\geq$ 27 m/min (Giersberg et al., 2021) of the conveyor belt. Handling stress may also be caused by drops to the floor and poorly designed systems where chicks become caught, trapped, smothered or crushed (Knowles et al., 2004).

3.11.5.3. Preventive measures

Slowing down the speed of the belts, removing steep gradients of the belt, avoiding a change in velocity between belts and rough handling of the chicks and ensuring proper belt design, timely maintenance and constant monitoring reduce handling stress (Knowles et al., 2004). This includes that staff should be trained in proper handling and surveillance. On-farm hatching is an effective preventive measure of handling stress, as handling is significantly reduced (van de Ven et al., 2009; de Jong et al., 2019, 2020; Souza da Silva et al., 2021; Jessen et al., 2021a).

3.11.5.4. Corrective and mitigative measures

If a chick has fallen off the belt or accidentally been dropped to the floor, care should be taken to lift it up using both hands to support the body to minimise the risk of inducing further stress due to improper handling.

- Avoid changes in velocity on conveyor belts greater than 0.4 m/sec, drop heights above 280 mm and speeds of $\geq$ 27 m/min to reduce handling stress.
- Train staff in proper handling and surveillance of the system to minimise handling stress.
- Use both hands to support the full body during handling to minimise handling stress.

3.12. The assessment of Animal Based Measures collected in slaughterhouses to monitor the level of welfare of broiler chickens on farms (specific ToR 2)

3.12.1. Introduction

This specific ToR considers broilers that will be sent to the slaughterhouse. It aims to identify for all broiler categories a list of ABMs that can be assessed and collected at slaughter and provide retrospective information on the welfare condition across populations or regions/countries.

The ABMs that help to identify more than one welfare consequence are preferred. These indicators are commonly referred to as 'iceberg indicators' (EFSA AHAW Panel, 2022c).

Recording ABMs at slaughter can provide information for assessment and benchmarking of broilers welfare on farm (Stärk et al., 2014; de Jong et al., 2016b; Mullan et al., 2021).

The full methodology and the starting list of ABMs considered potentially relevant for measurement at slaughter in broilers is presented in Appendix D.

3.12.2. Relevant ABMs

The outcome of the ABM screening and selection exercise is presented in Table 15 where the scoring of the specific criteria used to select the ABMs at slaughter are reported. Of the originally identified 16 ABMs, 9 passed the screening procedure and were submitted to the selection step. 'Total mortality' (on-farm), 'wounds', 'carcass condemnation' and 'footpad dermatitis' were selected as the most useful ABMs indicative of broiler on farm welfare. 'Dead-on-arrival' did not pass the screening phase because it was considered affected by the transport conditions.

Table 15: Ranking of ABMs for broilers based on the four criteria. Scores from 0 = absence to 4 = high. The weight of each criterion is in brackets. The ABMs that were selected are highlighted in grey

ABM	Assessment	Welfare consequence (weight = 6.5)	Technology readiness (weight = 1.5)	Already measured at slaughter (weight = 1)	Importance rated by the network (weight = 1)	Weighted score
Total mortality (on-farm)	*Ante-mortem*	4	1	4	4	**3.6**
Wounds	*Post-mortem*	3	3	2	2	**2.8**
Carcass condemnation	*Post-mortem*	3	1	3	3	**2.7**
Footpad dermatitis	*Post-mortem*	2	4	4	4	**2.7**
Dirtiness	*Ante-mortem*	3	1	1	1	2.3
Plumage damage	*Post-mortem*	2	3	1	1	2.0
Hock burn	*Post-mortem*	2	1	2	3	2.0
Breast blister	*Post-mortem*	1	1	2	2	1.2
Cellulitis	*Post-mortem*	1	0	2	1	1.0

In the following sections each ABM is described with its definition, interpretation, means of assessment and arguments for the selection (linking the scores and the scientific evidence in the literature).

3.12.3. Selected animal-based measures

3.12.3.1. Total mortality (on-farm)

Description of the ABM

Definition: Total mortality is the number of deaths in the flock. Since it will vary according to the age of the birds when the flock is slaughtered, a calculation of mortality rate is used to take this into account. Mortality rate, or death rate, is a measure of the number of deaths in a particular population, scaled to the size of that population, per unit of time.

The daily mortality rate is the number of broilers which have died in the house on the same day, including those that have been culled either for disease or other reasons, divided by the number of chickens present in the house on that day multiplied by 100. The cumulative daily mortality rate is the sum of all daily mortality rates up until the specified date or age. It is the cumulative daily mortality rate at the time of slaughter that is the measure of total mortality defined in the Council Directive 2007/43/EC[5]. This information is currently only required for flocks kept at a stocking density greater than 33 kg/m^2.

It is also useful to know the daily culling rate as well as the daily mortality rate. Furthermore cumulative daily values, determined at the end of each week of age, as well the cumulative values at the time of slaughter, give information on the pattern of mortality/culling over time. Having information on the total mortality and the total number of birds culled in a flock makes it possible to calculate the ratio of culled birds/birds found dead (EFSA AHAW Panel, 2010). Finally, it is relevant that these data are provided for all flocks.

Interpretation

Many factors will affect total mortality on the farm. High flock mortality can be caused by an outbreak of disease, e.g. gastro-enteric disorders and colibacillosis (Section 3.4.2.6), or problems with the environment in the building, e.g. heat stress (Section 3.4.2.9). Other factors affecting total mortality will be the chick mortality in the first week and the culling policy of the farmer throughout the whole period. Regarding chick mortality, it is suggested that the keeper often claims that this mortality was due to conditions at the hatchery, but this is rarely investigated further by the authorities (European Commission, 2018). Higher mortality is also found in chicks that were exposed to cold stress, e.g. during transport or at the farm during the first days (Heier et al., 2002), and mortality can be caused by chicks not starting to feed or drink once at the farm (de Jong et al., 2017). Excessively high temperatures for chicks can also be a problem and may result in dehydration (Xin and Harmon, 1996; Maman et al., 2019). Heat stress is a particular problem for growing broilers in mobile systems and can lead to very high mortality. It can be a problem in indoor systems, for example during a heat wave, and especially since such extreme weather conditions are becoming more frequent. Mortality of birds on free range can result from predation (Stahl et al., 2002). Fear reactions among birds may result in piling behaviour and birds may be found dead, often in the corners of the barn because of this panic response and consecutive smothering.

The worse the welfare consequence, the higher the mortality due to it. Even if a bird does not die, it may be necessary to euthanise it in a humane way. It is the potential pain and suffering of the bird before it dies or is culled that is of welfare concern. Culling of birds for welfare reasons is a way to minimise suffering, e.g. in lame birds (Knowles et al., 2008).

In summary, the higher the level of on farm mortality the higher the probability that there is a welfare issue on farm. 'Total mortality' is considered an iceberg indicator because it is related to many welfare consequences ('cold stress', 'heat stress', 'prolonger hunger', 'prolonged thirst', 'predation stress', 'sensory over or under stimulation' and 'gastro-enteric disorders'), although further investigation is necessary if the actual hazards are to be identified and prevented for future flocks on the farm.

Assessment

Timing of assessment: ante-mortem

According to the event report around the NCPs Network exercise (EFSA, 2021) total mortality on farm is communicated in most cases to the slaughterhouse, including a separate specification of the total culled animals. At the slaughterhouse, a high total mortality is reported to the competent authority leading, in some countries, to a farm inspection or to the obligation to reduce stocking density. Different threshold levels and several protocols exist among countries to assess this.

The data on mortality are collected up until the time the flock leaves the farm and should be provided separately from the data on dead on arrival at the slaughterhouse.

Current use of this ABM

This ABM is already recorded in the majority of the EU countries because of the current legislation on broilers. However, it may be that not all the measures proposed here are recorded or not for all flocks.

Considerations for use as a standard method

A standard method of recording total mortality, as daily cumulative mortality, has been presented. It was also presented that a distinction should be made between the number of birds found dead and those culled, for example expressed as a ratio.

Currently, to meet the criteria for the use of a stocking density greater than 33 kg/m^2, the cumulative daily mortality rate for at least seven consecutively checked flocks from the house should be below 1% + 0.06% multiplied by the age of the flock in days.

Total mortality is recorded by the farmer and there may be mistakes or intentional misrepresentation of figures. Even if the figures are correctly reported, not all dead birds in the flock are found. This may be because of the high density of the birds or a low light level in the barn resulting in dead birds being missed when the farmer is inspecting the flock. On free range the carcass may be removed by a predator and the mortality missed. Even if there is evidence of predation, the total number of birds missing may not be known. Whatever the reason, it is likely that the number of birds slaughtered will not be the same as the total number of birds placed in the barn minus those reported in the daily cumulative mortality, even if the number of birds removed for eventual sale separately is taken into consideration. There is the possibility for further investigation to identify the reason for this if there are consistent large discrepancies.

The weekly reporting of the daily cumulative mortality will provide information on the distribution of the mortalities over the rearing period. This may provide useful additional information about the reasons, e.g. it may be the case that high mortality in the first week is attributable to the hatchery or the transport of the chicks, and not to the conditions on the farm. Although impaired gait score assessed close to slaughter was found to be correlated with first-week mortality, it was not related to total on-farm mortality (Kittelsen et al., 2017). Whereas poorer uniformity of the flock has been associated with both first-week mortality and total mortality (Vasdal et al., 2019a). High mortality over one or two specific days may reflect extreme weather or a particular problem with the environment within the barn and therefore not be a good reflection of the overall level of welfare on the farm. More birds culled on farm have also been associated with an increase in total carcass rejects (Haslam et al., 2008). Indeed, correlations between welfare indicators and slaughterhouse outcomes showed a relationship between flock mortality and dead on arrival, FPD, leg problems and illness (BenSassi et al., 2019b) supporting the usefulness of this indicator.

Possibilities for automation

The number of birds culled will continue to be recorded manually, but there are an increasing number of robots that can patrol a broiler house to detect dead birds. There is already one system available commercially (see https://www.bigdutchman.de/de/gefluegelmast/aktuelles/detail/haehnchenmast-chickenboy-analyseroboter-herdengesundheit/ for a video). Another system developed by Liu et al. (2021a) has in addition a small removal system so that the caretaker does not need to touch the animal. There has also been research on the responses of birds to robots in the building, e.g. Dennis et al. (2020), Parajuli et al. (2020), although these robots were not specifically designed to detect dead birds. Nevertheless, both studies show few behavioural responses by birds to the robots, estimated to be no greater than how birds respond to a person walking in the system.

3.12.3.2. Carcass condemnations

Description of the ABM

Carcasses or parts of the carcass (in some types of broilers) that are unfit for use as food *(e.g. due to septicaemia, hepatitis, pericarditis, abscess, arthritis, emaciation, etc)* described as: number of birds, weight of the carcass or waste per group. This list is not exhaustive as condemnation might occur for many other reasons.

According to the Commission Implementing Regulation (EU) 2019/627[18], all slaughterhouses throughout the EU record carcass condemnations (including the part of the carcass condemned if only partially condemned (mostly in the case of slower-growing broilers)). The reason for condemnation is recorded primarily for food hygiene and meat inspection purposes. Apart from carcass contamination

[18] Commission Implementing Regulation (EU) 2019/627 of 15 March 2019 laying down uniform practical arrangements for the performance of official controls on products of animal origin intended for human consumption in accordance with Regulation (EU) 2017/625 of the European Parliament and of the Council and amending Commission Regulation (EC) No 2074/2005 as regards official controls. OJ L 131, 17.5.2019, pp. 51–100.

(e.g. with intestinal contents during evisceration) during the slaughter process, most of the reasons for condemning a carcass are linked to welfare relevant conditions. These conditions including hematoma, bruises, breast blister, ascites, dermatitis, and emaciation are undoubtfully associated with impaired animal welfare (Ellerbroek, 2019).

Interpretation

During abattoir meat inspection, broiler carcasses are potentially condemned upon detection of disease or lesions that reflect animal welfare in any of the stages prior to slaughter (i.e. including on-farm and transport, lairage).

In Germany the overall condemnation rate between 1% and 2% was reported until 2014 and since then there was an increase in 2017 to 2.8% (Ellerbroek, 2019). Fractures and bruising represent the most prevalent welfare problem related to carcass condemnation, followed by skin lesions or inflammation (Souza et al., 2018b). Other conditions such as arthritis, ineffective bleeding, and air sacculitis condemnation may reveal important welfare aspects (Souza et al., 2018b). Cellulitis is also a prevalent problem in broiler chicken and a reason for carcass condemnation (Norton, 1997).

The carcasses that are condemned are generally severely affected meaning that only the most severe cases are recorded. Other less severe conditions might not lead to condemnation and therefore not recorded.

The higher the rates of condemnation the more likely it is that there is a welfare issue on farm. Carcass condemnation is considered an iceberg indicator because it is related to many welfare consequences on-farm, although further investigation on it is necessary if the actual hazard is to be identified for prevention.

Assessment

Timing of assessment: *post-mortem*.

Current use of this ABM

All Food Business Operators must adhere to food safety legislation therefore all slaughterhouses already record this ABM for food hygiene purposes. Decisions on carcass condemnation is made after inspection by the Official Veterinary officers. Carcass condemnations is expressed as the number of carcasses condemned, as the weight of the condemned carcasses.

There is little available information on the use of condemnation data for animal welfare purposes, though many projects are underway (EFSA, 2021).

High levels of carcass condemnation can be used as a proxy of poor welfare, assuming that severe lesions or poor body condition (i.e. emaciation) had caused negative affective states such as pain and/or discomfort. However, as condemnation assessment addresses only the cases that are relevant for food human safety, low or expected levels of carcass condemnation might not necessarily reflect good welfare on farm.

There is a large variation in the recording of carcass condemnations throughout the EU. Differences reported are due to the terminology used, the type, number, and use of codes of classification and the use of electronic databases. Additionally, there is large variation between meat inspectors in the recording of the reasons for condemnation. Hence, it is difficult to compare data between different countries and/or slaughterhouses. Carcass condemnations due to other reasons than health and welfare (e.g. because of improper handling or of carcass contamination) must be excluded from the final score. There is a need for harmonisation of the criteria, both in and between MSs.

The data are recorded in all EU member states and are already available, but their use needs to be developed for welfare purposes. High levels of carcass condemnation can be used as a proxy of poor welfare, assuming that severe lesions or poor body condition (i.e. emaciation) had caused negative affective states such as pain and/or discomfort. However, as condemnation assessment addresses only the cases that are relevant for food human safety, low or expected levels of carcass condemnation might not necessarily reflect good welfare on farm.

Possibility for automation

Decisions on carcass condemnation is made after inspection by the Official Veterinary officers.

Currently, there is a prototype vision system (IRIS GDR), mainly used for carcass classification and resulting logistics. It measures weight, yield, of whole chickens and parts and decides whether condemnation affects the whole chicken or parts (Marel). This system supports the official veterinarian in identifying condemnation by measuring bruises, fractures, scratches, etc. However, information on the validation of these tools with expert inspectors are not publicly available BuRO (2022).

In Germany there is also a prototype camera to detect deep dermatitis on the carcass and ascites in broilers to support Official Veterinary officers (Mr Schulte-Landwehr, CLK GmbH, Germany, personal communication, 6 September 2022, email).

Moreover, developing automated and harmonised recording and electronic databases can result in a valid tool to enhance the traceability and to support animal welfare monitoring schemes across different slaughterhouses/countries.

3.12.3.3. Wounds

Description of the ABM

Definition: Soft tissue damage with or without rupture of the skin. Wounds comprise of all lesions to the skin, ranging from minor superficial punctiform spots to scratches to large open wounds that go deeper than the skin (Welfare Quality Network, 2019). It also includes bruises. It does not include bone lesions, wing fractures, beak issues or foot injuries.

The animal experiences negative affective states such as pain, discomfort and/or distress due to physical damage to the integument or underlying tissues (e.g. single or simultaneous occurrence of scars, multiple scratches, open or scabbed wounds, hematomas, swelling, and muscle damage).

Wounds are highly relevant for the welfare of broilers and perhaps even more for broiler breeders; due to the longer time they are kept and therefore the longer duration of the ABM.

Interpretation

'Wounds' are a good iceberg indicator as they are related to several welfare consequences on farm ('group stress', 'inability to perform exploratory or foraging behaviour' and 'inability to avoid unwanted sexual behaviour' resulting in 'soft tissue lesions and integument damage'). Most of the literature found on these soft tissue lesions and integument damage relates to broilers, with rather little on breeding birds. Wounds on the comb and at the back of the head can be used as a proxy of aggressive interactions between birds (Welfare Quality Network, 2019). In the event of feather pecking there are also wounds in the skin that might induce cannibalism. Wounds on the back of the neck and head in females, caused by males when mounting to mate, are seen in flocks with natural mating. The presence of scratches might be the result of broilers running over each other because of high stocking densities.

For use at a slaughterhouse, the determination of the age of the lesion is important to discriminate between those produced on farm and those caused by the transport or slaughter practices. In the case of bruises, the age might be possible to be estimated based on its colour (EURCAW-Poultry-SFA, 2020). Bruises older than 24 h (and likely to occur on farm) are light green, yellow-green and light-yellow coloured. Bruises less than 12 h old and caused during catching and transportation are from intense dark red to purple colour (Gregory et al., 1992). Additionally, bruises caused at the slaughterhouse during shackling can be distinguished for being bright red in colour (Bremner and Johnston, 1996).

Nevertheless, the assessment of the age of the bruises by the colour might have its limitation. While wing and leg bruises become lighter with the time, breast bruises become darker (Northcutt et al., 2000). Furthermore, the visual perception of yellow colour changes between observers leading to a low reliability and accuracy for estimating bruise age older than 48 h (Hughes et al., 2004). However, broilers usually do not spend more than 24 h from catching to being slaughtered. Therefore, bruises from light purple to yellow are most likely to be caused at the farm level (EURCAW-Poultry-SFA, 2020).

Assessment

Timing of assessment: *post-mortem*

Assessment of wounds *post-mortem* after scalding is more reliable than *ante-mortem*, as there are significant limitations associated with *ante-mortem* assessment. During *ante-mortem* inspection some wounds may not be visible when the animal is alive due to the presence of feathers that cover the skin and impair visibility (EURCAW-Poultry-SFA, 2020). Furthermore, it can be difficult to inspect each animal, especially when birds are in a crate. Moreover, cleanliness of the birds affects the visibility of the lesions. Variable environmental conditions (e.g. poor lighting and dust) also limit the *ante-mortem* assessment. The visibility of the lesions is improved by clean carcasses being presented to the observer in a standardised way, allowing assessment of wounds in the entire batch. In either case, the presence of artefacts (e.g. wounds originating from waterbath stunning or processing, i.e. *post-mortem*) and visual limitations show that it is important to adjust any assessment protocols to the practical situation of a slaughterhouse.

Current use of this ABM

According to the EFSA (2021) report, less than half of the MS representatives who responded to the question recorded wounds at slaughter. Moreover, data on wounds are currently not often used for assessing animal welfare conditions on the farm but for meat quality and food safety purposes.

Considerations for use as a standard method

Wound assessment post-mortem can be performed. However, artefacts such as damage due to carcass procedures need to be recognised by the observer to minimise any potential bias of the results. Therefore, the staff needs to be trained to distinguish artefacts (i.e. lesion produced after slaughter) from wounds. Lesions can be due also to transport, however, they can be differentiated from older wounds, so the ABM is still valid for assessing welfare on farm. In some Dutch slaughterhouses the percentage of dressed carcasses with wounds are scored. Carcasses are assessed on the breast side and considered injured when dark red large (diffuse) hemorrhages from three centimetres (diameter) on the wing or the leg are present (IKB-Kip, 2021). In conclusion, there is a need for a harmonised scoring system to monitor wounds in broilers.

Possibilities for automation

At the slaughterhouse, wounds can be assessed in the carcass by computer vision analysis. There is already a prototype, Vetinspector, made by IHFood in Denmark (www.ihfood.dk), for the *post-mortem* inspection of lesions in chickens (Sandberg et al., 2022). It consists of two camera-stations that detect lesions on the outside of the carcass and on the viscera. The image-analysis algorithm is a neural network/artificial intelligence model, where the ability to classify lesions correctly are improved with every new carcass photographed. The model is capable of analysing pictures of carcasses at any slaughter speed. The technique still needs validation for the identification of the different types of lesions and the relationship with on-farm animal welfare.

The Intelligent Reporting, Inspection & Selection system (IRIS; Marel) consists of a digital camera, LED lighting and advanced recognition software that uses shape, colour and texture to detect wounds in the carcass (https://marel.com/en/search?industry=Poultry&q=IRIS).

3.12.3.4. Footpad dermatitis

Description of the ABM

Definition: Type of contact dermatitis affecting the foot and toe pads. Contact dermatitis is inflammation of the subcutaneous tissue leading to hyperkeratosis, necrosis or ulcerations (Section 3.4.2.21).

According to the Council Directive 2007/43/EC[5] and in the context of the controls performed under the Regulation (EC) No 854/2004[19], the official veterinarian shall evaluate the results of the post-mortem inspection to identify possible indicators of poor welfare conditions. An abnormal level of contact dermatitis is mentioned in this list, but no further details on how this should be assessed or what is an abnormal level are given. That is despite the fact that in Appendix IV of the Proposal for a Council Directive (European Commission, 2005b), there is a section on monitoring and follow-up at the slaughterhouse where a method is presented to determine the level of FPD in a flock along with a maximal score for an acceptable level of FPD. The scoring system presented is 0 (no footpad lesion), 1 (minor footpad lesion) and 2 (severe footpad lesion). A scoring system of 0–2 had already been developed (Ekstrand et al., 1998; Berg and Algers, 2004; Welfare Quality Network, 2019). However, as part of work related to the Implementation of Article 6.2 of Council Directive 2007/42/EC[20] more details on the assessment rules for each level were proposed and slightly revised definitions were

[19] Regulation (EC) No 854/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. OJ L 139, 30.4.2004, pp. 206–320.

[19] Commission Directive 2007/42/EC of 29 June 2007 relating to materials and articles made of regenerated cellulose film intended to come into contact with foodstuffs. OJ L 172, 30.6.2007, pp. 71–82.

suggested by EFSA (EFSA, 2013). These revised definitions were based on research on the 0–2 scoring system and another scoring system with a 5-point scale (Michel et al., 2012).

Interpretation

A high incidence of FPD is associated with the welfare consequences 'soft tissue lesions and integument damage' as well as 'restriction of movement' on farm. It is an ABM that reflects the quality of the litter in the barn and is therefore relevant to the whole broiler industry since almost all broilers and most broiler breeders are kept in floor systems with litter. Measurements of FPD on-farm correlate with slaughterhouse measurements supporting the use of slaughterhouse data (de Jong et al., 2016b). Higher levels of FPD have also been found to correlate with higher gait scores (Granquist et al., 2019). The correlation of very dirty feathers and severe FPD further support litter humidity to be the common underlying cause (Saraiva et al., 2016).

Histological studies have found that visual macroscopic scoring of FPD reflects histological findings (Heitmann et al., 2018; Piller et al., 2020). These inflammatory and necrotic lesions are most certainly painful. They have also been found to be associated with the presence of pathogens and a high percentage of birds affected with severe footpad lesions could be predictive of the flock being Campylobacter-positive (Alpigiani et al., 2017). The most severe lesions were also found to be associated with higher microbiological counts for *E. coli* and *Staphylococcus* spp (Alpigiani et al., 2017). Thus, the more FPD that is observed (higher score and higher number of individuals in the flock affected), the higher the welfare consequences.

During the selection exercise (Appendix D), FPD was given a score of 2 because it is mainly related to the welfare consequence 'soft tissue lesions and integument damage' and 'restriction of movement'. These two welfare consequences have a huge impact on the overall welfare of broilers; therefore, the ABM was selected.

It is relevant to note that since FPD started to be recorded at slaughter, some countries have registered a decrease in its prevalence (e.g. Denmark). If FPD is present, the welfare is impaired, but if it is absent, the welfare of the birds might still be impaired (by the same and/or other welfare consequences) and other ABMs will show it. So even if it is considered an iceberg indicator, it is not sufficient alone and there is a need to record additional ABMs at slaughter to assess welfare.

Assessment

Timing of assessment: *Post-mortem*

This is suggested, mainly because the birds are hung on the shackles and their feet are clean. This makes the underside of the feet easy to inspect. It should be noted that feet can be scored from birds on the moving line or scored later, e.g. from a box, after the feet have been separated from the bird (EFSA, 2013).

Current use of this ABM

The scientific NCPs Network (EFSA, 2021) reported that FPD is assessed in the majority of EU MSs. The Network considered this ABM essential when assessing animal welfare.

In some member states, not all batches are examined, but only a sample. Most common sample sizes for visual assessment consist of 100 birds/flock or 100 legs/flock (in some countries legs are randomly sampled, while in other countries legs are sampled from the same side in all birds). On the other hand, if the assessment is automated (using videos), all animals of the flock can be inspected. The resulting data on FPD assessment are usually recorded in electronic databases.

Many MSs reported the use of more complex scoring methods, ranging from skin discoloration or very small superficial lesions, to ulceration or severely swollen FPD. In a few member states the total count of the affected animals is the method used. In some member states however, a specific scoring method is lacking.

All the member states that are recording FPD routinely have defined a threshold. Values of FPD over this threshold will lead to some consequence for the farm of origin. These consequences potentially include notification to the farmer, an official inspection at the farm or the exclusion of the flock from high-quality labelling schemes. In some country farmers can apply to have economic support for a reduction in FPD.

In Denmark when monitoring of FPD was implemented in 2002 with predefined limits that triggered sanctions, there was a dramatic decline in flock lesion in the following three years followed by a minimal decline afterwards (Kyvsgaard et al., 2013).

Considerations for use a standard method

In most cases a three-point, four-point or five-point scoring system is used to describe the macroscopic findings when the underside of the foot is inspected, and the area and type of damage compared to a standardised series of photographs. A problem is that the assessment at the slaughterhouse is not homogeneous in all the MS (EFSA, 2021), both in the scoring system used and in the overall methodology. In some cases, the data are recorded but it is not used as part of welfare assessment.

When manually assessing FPD, the level of training is crucial to ensure reliability in the assessment, even if the same scoring system and methodology is used. It is important also to check this official control with other independent raters, as there is evidence in one study that the official scoring may have underestimated the occurrence and severity of lesions (Oliveira et al., 2017). A difference was found when scoring footpads from conventional and organic broilers (Lund et al., 2017). This reflected different characteristics in the footpad of the organically reared birds, e.g. hyperkeratosis, compared to, e.g. ulcers, found on the feet of conventionally reared broilers (Riber et al., 2020). Differences have also been found depending on whether the observations are made at the running evisceration line or from feet taken from the line for an individual assessment and the authors suggest the latter to be better (Louton et al., 2022). All these emphasise the importance of standardised and well-defined classification system and training.

There is evidence of genetic effects (Allain et al., 2009; Zampiga et al., 2019) and seasonal effects (de Jong et al., 2012b; Kyvsgaard et al., 2013; Dinev et al., 2019) on FPD scores. Knowledge about such effects can help inform efforts to reduce FPD in flocks, and progress can be benchmarked.

Possibility for automation

The scoring at the slaughterhouse has opened the possibility for automated systems to assess the extent of the dermatitis (Vanderhasselt et al., 2013; Kaewtapee et al., 2021; Louton et al., 2022). According to the recent BuRO (2022), some systems are already commercially available for assessing FPD in broilers. Examples are the systems from Meynm CLK GmbH or RVO.nl (Meyn Food Processing Technology B.V, 2018; CLK GmbH, 2022a, RVO.nl, 2020). In brief, these systems use cameras, videos and digital imaging to differentiate areas of the foot that are discoloured and then compare the area of this (e.g. number of pixels) with the area of the total foot. Automated systems showed that more birds can be assessed per flock and reliability of scoring is higher than visual assessment. In studies to develop these automated systems, comparisons are made between the automated and human expert scoring showed a high correlation at flock level (BuRO, 2022). Because of that, in some MSs, these systems are already authorised to be routinely used in the slaughter line.

Differences were found among the scoring method used for FPD within the different tools (BuRO, 2022) limiting the comparison of FPD measured at slaughter.

4. Conclusions and recommendations

Please note that the certainty level of the conclusions is provided between brackets except for those with a certainty > 90% in which no certainty level is indicated.

The conclusions and recommendations in this Section 4.1 concern only the highly relevant welfare consequences identified and described in the Section 3.4. The total number of welfare consequences that were identified as highly relevant per system does not reflect the overall level of welfare in that system. This section focusses on conclusions on welfare consequences, their ABMs, hazards and general points about prevention, correction and mitigation. The recommendations about hazards (quantitative figures) that are common for different welfare consequences are described in the discussion of the ToR (Sections 3.6–3.9).

To avoid repetitions, each welfare consequence will be described only for the animals' categories for which it applies.

4.1. Answers to General ToRs

4.1.1. Bone lesions

4.1.1.1. Conclusions

1) 'Bone lesions' have been identified as a highly relevant welfare consequence in broiler breeders in all housing systems.

2) 'Keel bone fractures' is considered as the most important ABM for 'bone lesions' in broiler breeders. This ABM has a moderate sensitivity and moderate specificity when assessed by the palpation method and a high sensitivity and high specificity when using radiographs.
3) There is a lack of information on the prevalence of bone lesions in broiler breeders.
4) 'Keel bone fractures' in broiler breeders induce negative affective states such as pain as shown in laying hens (66–100%).
5) 'Keel bone fractures' have been shown to occur in fast-growing as well as in slower-growing broiler breeders. The prevalence differs between hybrids which means that genetic has an impact on occurrence of keel bone fractures and that selection to prevent it is possible.
6) The cause of keel bone fractures is multifactorial including laying performance of the breeders and/or occurrence of traumas due to collisions and falls.
7) The provision of perches and elevated structures increases the prevalence of 'keel bone fractures' (> 50–100%).
8) The hazard 'inappropriate feeding content' related to calcium and phosphorus composition increases the risk of bone fractures.
9) Ramps can be used in breeders housed in multi-tiers to access the different levels to prevent keel bone fracture due to collisions.
10) Corrective measures do not exist for keel bone fracture.

4.1.1.2. Recommendations

1) More research is needed to specify the recommendations about elevated structures that fulfil the behavioural needs of the broiler breeders and avoid keel bone fractures.
2) Reduction of keel bone fractures should be added to the genetic selection traits.
3) The feed levels of phosphorous and calcium as well as supplementation of minerals, Vitamin D, and fatty acids and the feed composition and supply should be optimised to ensure bone strength.
4) More research in broiler breeders is needed to assess the prevalence of keel bone fractures in all the different husbandry systems.

4.1.2. Cold stress

4.1.2.1. Conclusions

1) 'Cold stress' has been identified as a highly relevant welfare consequence for day-old chicks hatched in hatchery and broiler chickens reared in mobile housing systems with outdoor access.
2) 'Cold stress' leads to stress and/or negative affective states and/or distress and potentially increased mortality in day-old chicks.
3) During the first week of life chicks will experience cold stress when the temperature is below 30°C – the lower limit of their thermal comfort zone (30–35°C) – at the hatchery or at placement.
4) In broilers, cold stress will usually start at a temperature below 17°C – the lower limit of their thermal comfort zone (17–21°C), but the exact temperature depends on the age, weight, hybrid and sex of the bird and stocking density, degree of adaptation to the low temperature, duration of exposure, humidity and wind chill (66–100% certainty). A lower temperature in the veranda or outdoor range will not lead to cold stress if the chickens can enter the barn where the temperature is kept within their comfort zone.
5) ABMs to assess 'cold stress' in day-old chicks are 'huddling', 'cloacal temperature', 'surface temperature', and 'distress calls'. 'Huddling', 'cloacal temperature' and 'surface temperature' have high sensitivity and specificity. 'Lethargy', 'distress calls' and 'mortality' are iceberg indicators that can be used to assess 'cold stress' in addition to the other ABMs.
6) The ABMs to assess 'cold stress' in broiler chickens are 'huddling' and 'cloacal temperature'. They have high sensitivity and specificity. 'Lethargy' is an iceberg indicator that can be used to assess 'cold stress' in addition to the other ABMs.
7) The main hazard for 'cold stress' is a low effective temperature.
8) Preventive measure for 'cold stress' consist in keeping birds in there thermal comfort zone. In day-old chicks, it can be achieved by whole house heating or local heating using brooding rings, with a heating source keeping a temperature between 32°C and 35°C. In broiler chickens reared in mobile housing, it could be achieved by providing in the house a

heating system or a local heater until the chickens reach 4 weeks of age, adequate bedding for floor isolation and preventing draught.
9) Corrective measures include adjusting ventilation and increasing the room temperature.

4.1.2.2. Recommendations

1) Ensure an appropriate temperature between 30°C and 35°C for day-old chicks in the hatchery, during transport (EFSA AHAW Panel, 2022a) and on the farm at placement until one week of age to avoid cold stress.
2) Farmers should inspect young chicks more than once a day during the first week of life to adjust the climate to their thermal comfort zone (30–35°C) if needed.
3) Farmers should pay attention to indicators of cold stress such as 'huddling' when inspecting the flock.
4) In mobile housing systems with outdoor access, an environmental temperature of at least 17°C should be provided in the barn (depending on age, sex, weight, hybrid, and stocking density) and chickens should always be able to access the barn.
5) When broiler chickens in mobile systems with outdoor access show signs of cold stress such as huddling, the temperature in the house should be increased, and if draught is present the ventilation should be adjusted to avoid it.

4.1.3. Heat stress

4.1.3.1. Conclusions

1) 'Heat stress' has been identified as a highly relevant welfare consequence for broiler chickens in mobile housing.
2) Birds can remain inside, either in the attempt to escape from exposure to sunshine and high effective temperature in the outdoor/free-range area, or due to management practices during the first weeks after placement. In these conditions, the barn may be crowded and overheated, leading to high mortalities due to heat stress.
3) In conditions above the thermoneutral zone, birds that are sitting on the litter cannot dissipate heat from their legs and belly due to the insulating effect of the litter. This situation may lead to induce heat stress and high mortality.
4) The thermal comfort zone varies widely with the age and hybrid of the chicken. The higher the age, the lower the upper critical temperature (UCT), and the more fast-growing the lower the UCT.
5) ABMs of 'heat stress' are 'panting' and 'birds holding their wings away from the body' and 'lethargy'. 'Panting' has high sensitivity and high specificity. 'Wings held away from the body' has moderate sensitivity and high specificity. 'Lethargy' is an iceberg indicator that can be used in addition to other ABMs.
6) The main hazard of 'heat stress' is the use of mobile houses that lack insulation, are poorly ventilated, or mobile houses placed in direct solar radiation combined with too high effective temperature.
7) Lack of shelter in the outdoor range is also a hazard for 'heat stress'.
8) Preventive measures are: placing the mobile house under the shade in summer months, insulating the house and providing mechanical or at least passive ventilation, and natural shelter in the outdoor range.
9) The best mitigative measure is active ventilation. Passive cross-ventilation on opposing sides (without draught in bird areas) preferably with one position at the highest point in the mobile house is the minimum to be able to avoid heat stress.

4.1.3.2. Recommendations

1) Mobile houses should be located in such a way that direct solar radiation is prevented (in the shade).
2) Additional shelter, preferably natural shade (such as trees and/or bushes), should be provided to prevent direct solar radiation in the outdoor area.
3) The minimum ventilation to avoid heat stress should be passive cross-ventilation, but preferentially active ventilation should be present.

4) Reducing stocking density, by thinning or by providing additional spatial levels through elevated structures (that animals should be able to utilise) should be provided to help the birds to regulate their body temperature.

4.1.4. Inability to perform comfort behaviour

4.1.4.1. Conclusions

1) 'Inability to perform comfort behaviour' has been identified as a highly relevant welfare consequence for broiler chickens kept on floor systems and broiler breeders kept in individual and collective cages.
2) Comfort behaviour is considered a behavioural need for the chicken. Related ABMs for 'inability to perform comfort behaviour' are 'dustbathing', 'preening', 'wing and leg stretching', 'wing flapping', and the iceberg indicator 'feather and body dirtiness'. 'Dustbathing' has high sensitivity and specificity. 'Preening' has a moderate sensitivity and a low specificity. 'Wing and leg stretching' has a moderate sensitivity and high specificity. 'Wing flapping' has high sensitivity and low specificity. 'Feather and body dirtiness' is an iceberg indicator that can be used in addition to the other ABMs.
3) One biological function of preening and dustbathing is to help keep the plumage in a good condition, facilitating regulation of the body temperature. Good litter stimulates and enables dustbathing and preening. For dustbathing, birds prefer litter material with a fine structure, i.e. having a small particle size that can get between the feathers, such as that of sand or peat and with a low lipid content. Birds preen while positioned on the floor but also while sitting on perches or elevated areas. Birds need sufficient illumination to perform comfort behaviour.
4) In floor systems, lack of space (per bird) or poor-quality litter (e.g. humid or caked) are the main hazards for 'inability to perform comfort behaviour'.
5) In cages, the complete absence of litter or insufficient litter are the main hazards that prevent realisation of functional dustbathing in broiler breeders. Limited space allowance and low height of cages as well as lack of perches are the main hazards that restrict wing and leg stretching and wing flapping.
6) Measures to mitigate the 'inability to perform comfort behaviour' in cage systems are addition of clean and friable litter or the provision of dust bathing material in separate trays for floor systems and cage systems, respectively.
7) The only measure to prevent the inability to dustbathe is provision of new, clean, loose litter.
8) Providing more space per bird and increasing the height in unfurnished as well as furnished collective cages will contribute to the ability to perform comfort behaviours other than dustbathing.
9) In floor and aviary systems, a reduced stocking density and continuous access to dry and friable litter will mitigate the 'inability to perform comfort behaviour'.

4.1.4.2. Recommendations

1) Individual cages should not be used as they prevent most comfort behaviours due to lack of space, elevated areas and dry and friable substrate. It is recommended to use only non-cage systems where litter and perches for breeders, or elevated structures for broilers, are provided, thereby enabling birds to perform comfort behaviours.
2) Litter material that is dry and friable should be available at all times. The composition of the litter should stimulate dustbathing (fine particles and low lipid content). Re-scattering is recommended.

4.1.5. Inability to perform exploratory and foraging behaviour

4.1.5.1. Conclusions

1) 'Inability to perform exploratory or foraging behaviour' has been identified as a highly relevant welfare consequence for broiler chickens kept in floor systems, and for broiler breeders kept in individual as well as collective cages.
2) The inability to perform exploratory or foraging behaviour will lead to frustration, which might develop into abnormal behaviours, e.g. stereotypic behaviour. Birds prefer to forage

in litter that contains palatable particles. Inability to perform exploratory and foraging behaviour might lead to decreased or complete lack of foraging – characterised by the ABM 'walking, scratching and pecking' – in broilers as well as in breeders. 'Walking, scratching and pecking' is an ABM with high sensitivity and moderate specificity.

3) Abnormal behaviours such as severe pecking can be assessed through the following ABMs: 'plumage damage' or 'injurious pecking', both of which are more likely to be found in adult broiler breeders. 'Plumage damage' and 'injurious pecking' are iceberg indicators that can be used to assess the inability to perform exploratory and foraging behaviour in addition to the ABM 'walking, scratching and pecking'. The extent of the expression of exploratory and foraging behaviours is influenced by the hybrid and their associated growth rate, the husbandry system, and management. In particular, main hazards that impair the performance of exploratory and foraging behaviour are high stocking densities, fear, impaired locomotor health (especially lameness), lack of dry and friable litter as well as lack of perches.
4) In the absence of environmental enrichment, exploratory and foraging behaviour will be expressed less frequently.
5) Exploratory and foraging behaviour reduces the risk of locomotory problems.
6) Access to a covered veranda stimulates the birds to perform exploration and foraging by decreasing the stocking density inside the barn as well as at the veranda, thereby providing the birds more opportunity for exploration and foraging. As a mitigative measure, addition of clean, friable litter and scattering feed on the litter can stimulate foraging and exploratory behaviour.

4.1.5.2. Recommendations

1) It is recommended that cages are not used.
2) If cages are to be used, e.g. for individual data collection, they should not be used during the entire life of the birds but for as short time as possible. In individual cages, birds should be provided with dry, friable litter/material that is available all the time, accessible perches not impairing the movement in the cage and a nest box for females.
3) Broiler breeders should be kept in groups (at least two animals, ratio of male to female not higher than 1/10) and in systems where litter and resources such as perches, nests and dust baths are provided and available at all times.
4) Litter material should be of a good hygienic quality and managed in such a way that it is always dry and friable, so it can be used for scratching and pecking according to the bird's motivation to forage. The composition of the litter should stimulate foraging (e.g. of varying particle size and structure).
5) Manipulable material and objects in addition to litter should be provided to stimulate exploration and foraging. Three-dimensional structures should be provided to stimulate exploration.
6) Access to a covered veranda is recommended for all broiler categories.
7) In addition to the covered veranda, it is recommended to provide an adequately structured and enriched free-range area that will encourage even more exploration and foraging.
8) In case of outdoor access, an interspersed covered veranda is recommended to encourage the chickens to access the free range.
9) As increasing space allowance supports foraging and exploration behaviour, low stocking densities or thinning during the rearing period to decrease the stocking density encourage this behaviour.

4.1.6. Gastro-enteric disorders and other infectious diseases (GED)

4.1.6.1. Conclusions

1) GED is a highly relevant welfare consequence in all housing systems for broiler chickens.
2) GED leads to watery faeces and diarrhoea that lead to wet litter, body and feather dirtiness and contact dermatitis, thereby decreasing chicken welfare.
3) ABMs identified are 'plumage/body dirtiness', 'footpad detematitis (FPD)', 'cloacal temperature', 'lethargy', 'impaired growth rate' and 'mortality'.
4) Multiple hazards cause GED such as host factors related to feed composition and management (e.g. abrupt transition to a new feed regimen), environmental factors (high

temperature and humidity in the broiler house) and infectious agents (viruses, bacteria, parasites).

5) Stress levels associated with poor environmental and/or management conditions negatively affect the gut microbiota making the birds more susceptible to disease.
6) Good quality feed (examples also include providing feed in pellet and adding wheat to the feed supports digestive function), combined with regular cleaning and disinfecting of feed and water equipment, including the removal of caked and mouldy residues lodged in the system, help prevent GED.

4.1.6.2. Recommendations:

1) An abrupt change in feed composition during rearing of chickens should be avoided.
2) Biosecurity (e.g. cleaning using a detergent followed by an approved disinfectant) should be applied to avoid infectious gastro-enteric disorders.
3) Broiler farms should be provided with good quality feed, combined with regular cleaning and disinfecting of feed and water equipment, including the removal of any caked and mouldy residues lodged in the system.

4.1.7. Prolonged hunger

4.1.7.1. Conclusions

1) 'Prolonged hunger' has been identified as a highly relevant welfare consequence in day-old chicks experiencing delayed access to feed and in broiler breeders experiencing feed restriction practiced avoiding obesity causing health and fertility problems.
2) Day-old chicks subject to feed deprivation longer than 48 h (from hatching to access to feed at placement) will experience 'prolonged hunger' which is detrimental to their welfare.
3) ABMs identified for day-old chicks are the iceberg indicators: 'body weight loss' between hatching and placement on the farm and 'mortality', for example calculated during the first week of life or during the total growth period.
4) ABMs identified for broiler breeders are 'impaired growth rate', 'polydipsia', 'stereotypic behaviour' and 'injurious pecking'. 'Impaired growth rate' has high sensitivity and low specificity. 'Polydipsia' has low sensitivity and moderate specificity. 'Stereotypic behaviour' and 'injurious pecking' are iceberg indicators that can be used in addition to other ABMs.
5) In day-old chicks, the most important hazard is post-hatch feed deprivation, which is on average 48 h (range 36–60 h). This can be caused by a long hatch window, long chick processing, long holding period and/or long transport duration.
6) Hatching day-old chicks on farm prevents 'prolonged hunger' since food is available to the chicks immediately after hatching.
7) Hatchery systems that provide moist feed (thereby providing food and water) may reduce the period where day-old chicks are experiencing 'prolonged hunger', as the chicks will then only be without access to feed during the hatchery procedures and later during transport.
8) The higher the growth rate in the commercial broiler, the higher the (potential) growth rate is in the broiler breeders (e.g. fast growing lines). However, to be able to live through production and be fertile, the higher the feed restriction that needs to be applied and the more severe the 'prolonged hunger' of the broiler breeders.
9) The mitigative measures to apply for broiler breeders have limited effect and are described in Section 3.4.2.7.

4.1.7.2. Recommendations

1) If 'prolonged hunger' is to be prevented, day-old chicks should be hatched on farm with immediate access to feed and water to prevent prolonged hunger.
2) More research is needed to clarify the welfare impacts of using systems providing moist feed in the hatcher.
3) If chicks cannot be fed before placement on the farm, the time between hatching and placement should be kept as short as possible and, in any case, not exceed 48 h post-hatch.
4) Genetic selection should promote hybrids that do need to be feed restricted in order to keep the broiler breeders healthy and productive and avoid 'prolonged hunger'.

4.1.8. Prolonged thirst

4.1.8.1. Conclusions

1) 'Prolonged thirst' has been identified as a highly relevant welfare consequence in day-old chicks experiencing delayed access to water after hatching and in broiler breeders experiencing water restriction practiced to avoid polydipsia and/or water wasting during feed restriction periods.
2) Day-old chicks subject to water deprivation longer than 48 h (from hatching to access to water at placement) will experience 'prolonged thirst', which is detrimental to their welfare.
3) ABMs identified to assess 'prolonged thirst' in day-old chicks are 'mortality' and 'body weight loss' between hatching and placement on the farm, as well as 'lethargy'. These three ABMs can be considered iceberg indicators.
4) In day-old chicks, the most important hazard is post-hatching water deprivation which is on average 48 h (range 36–60 h). This may be caused by a long hatch window and/or long chick processing and/or long holding period and/or long transport duration. The most important hazard for broiler breeders is the water restriction practiced to avoid polydipsia.
5) ABMs identified for broiler breeders are the 'voluntary water consumption test' and the 'pinch test'. The 'voluntary water consumption test' has high sensitivity and high specificity. The 'pinch test' has low sensitivity and high specificity. 'Stereotypic behaviour' is an iceberg indicator that can be used in addition to other ABMs.
6) Too high effective temperature (above 35°C) during the period holding day-old chicks in boxes is another hazard leading to 'prolonged thirst'.
7) Hatching day-old chicks on-farm prevents 'prolonged thirst' before placement since water is available to the chicks immediately after hatching.
8) Special management systems (e.g. nipples avoiding water spillage, slatted floor, adapted ventilation) in alternative systems for broiler breeders to avoid the need for water restriction.
9) Hatchery systems providing water or moist feed may reduce the duration of prolonged thirst, as the chicks will then only be without access to water during the hatchery procedures and transport.
10) Providing water (via gels) combined with light during transport will also mitigate thirst before placement (certainty 66–100%).

4.1.8.2. Recommendations

1) Day-old chicks should be hatched on farm to prevent 'prolonged thirst'.
2) More research is recommended on the welfare impact of systems providing water or moist feed in the hatcher.
3) The time between hatching and placement should be kept as short as possible and, in any case, less than 48 h post-hatching.
4) Water should not be restricted for broiler breeders.
5) Special management systems (e.g. nipples avoiding water spillage, slatted floor, adapted ventilation) should be used in alternative systems for broiler breeders.

4.1.9. Handling stress

4.1.9.1. Conclusions

1) 'Handling stress' has been identified as a highly relevant welfare consequence in day-old chicks hatched in hatchery and in broiler breeders kept in individual cages.
2) Chickens react strongly to handling, especially to being carried upside down and when the full body is not supported from underneath. Handling is stressful and associated with negative affective states such fear and possibly also pain.
3) Day-old chicks experience handling stress when subjected to procedures performed by automatic systems, such as those involving rollers and high-speed conveyor belts. Broiler breeders kept in individual cages are handled to collect sperm, to perform AI and to collect individual data.
4) ABMs for day-old chicks include 'chick-righting time', 'orientation and posture on the conveyor belts', 'chicks falling on the floor', 'fear response' and 'mortality'. 'Chick righting

time' has low sensitivity and low specificity. 'Chicks falling on the floor' has low sensitivity and high specificity. 'Orientation and posture on the conveyor belt' have high sensitivity and low specificity. 'Fear response' and 'mortality' are iceberg indicators that can be used in addition to the other ABMs.

5) ABMs for 'handling stress' in broiler breeders include 'escape attempts' to avoid capture and 'resistance to handling'. 'Escape attempts' has high sensitivity and moderate specificity and 'resistance to handling' has a low sensitivity and high specificity.
6) Change of velocity of the conveyor belts, drop heights, and badly designed conveyor system components are hazards for handling stress in day-old chicks at the hatchery.
7) Animal handlers that are poorly trained, under time pressure and/or fatigued can lead to rough handling of broiler breeders, which constitutes a hazard for handling stress.
8) Handling stress in day-old chicks can only be prevented by on-farm hatching and associated absence of handling. It can be mitigated by reducing the speed of the conveyor belts, improving the design to reduce drop heights and handling chicks gently. Chicks should be handled for as short time as possible.
9) Handling stress in broiler breeders associated with AI can be prevented by housing females and males together. If the birds need to be handled, potential mitigative measures are to habituate the birds, to reduce the duration of the handling and to have well-trained staff who also understand the importance of habituating birds to being handled.

4.1.9.2. Recommendations

1) Handling should be carried out in a way to minimise fear, stress and injury to the birds involved, while at the same time being as short as possible.
2) Staff should be trained in order to apply good handling procedures.
3) If handling is to be repeated, as may be the case with broiler breeders (e.g. AI), staff should apply good handling procedures to minimise bird resistance to capture and during handling.
4) When handled manually, day-old chicks should be handled using both hands to support the full body.
5) On-farm hatching should be promoted to spare day-old chicks from handling stress.
6) When manually handled, chickens for meat production and broiler breeders should be carried upright, by maintaining the wings close to the body, and not being held by their neck or wings, or inverted. No birds should be swung, thrown or dropped during the process of handling.

4.1.10. Isolation stress

4.1.10.1. Conclusions

1) 'Isolation stress' has been identified as a highly relevant welfare consequence in broiler breeders housed in single cages.
2) 'Stereotypic behaviour' (pacing, pecking at the empty feeder, spots, or own feathers or feathers of conspecifics) and 'fear response' are considered as ABMs for 'isolation stress' and are iceberg indicators.
3) The main hazard is single housing. Isolation stress cannot be prevented in this housing system.

4.1.10.2. Recommendations

1) Single housing should not be used and, in case it cannot be avoided, it should be restricted to short time periods.
2) If broiler breeders have to be housed in individual cages, they have to be provided with visual (females) and auditory contact (both sexes) with other birds.
3) It is recommended to develop alternative methods to collect the type of data that requires birds kept in isolation in individual cages. Options may include using precision livestock farming techniques when animals are kept in groups or alternative selection strategies based on keeping genetically related individuals together, to avoid isolation.

4.1.11. Locomotory disorders

4.1.11.1. Conclusions

1) 'Locomotory disorders' have been identified as a highly relevant welfare consequence for broiler chickens kept in floor systems with and without access to a covered veranda.
2) Lameness has a severe impact on behaviours and may impair the individual bird from reaching the water and food supply, leading to other welfare consequences such as 'prolonged hunger' and 'prolonged thirst' and to negative affective states such as discomfort or pain. Impaired locomotion will lead to an impairment of the possibility to fulfil behavioural needs such as exploratory and foraging behaviour.
3) ABMs identified for locomotor disorders are 'leg deformation' and 'walking impairment' which is commonly measured with the gait score. 'Leg deformation' has low sensitivity and high specificity and 'walking impairment' is an iceberg indicator that can be used in addition to other ABMs.
4) High growth rate is one of the main hazards leading to locomotory disorders. These problems are also impacted by genetics. Slower-growing hybrids have a lower risk of locomotory disorders than the fast-growing hybrids.
5) Space allowance is another hazard, and is positively correlated with walking ability as the birds have the opportunity to exercise and to be active.
6) A third hazard is impaired litter quality (e.g. humid, caked). This is an important hazard for FPD and hock burns, impairing locomotory function.
7) High stocking density and low locomotor activity aggravate the problem of locomotory disorders.
8) Preventive measures include providing and maintaining good quality litter.
9) An adjusted diet (e.g. with a lower energy content) is a way to improve the mobility of the chicken, by slowing down the growth rate.
10) Environmental enrichments that encourage the locomotor activity will reduce locomotory disorders (66–100%).
11) Increasing space allowance will stimulate activity and improve mobility of the chickens. This can be done by providing a covered veranda, thus extra space and enrichment, which help to reduce locomotory disorders (66–100%).
12) Providing elevated resting places reduces contact time with poor litter and the consecutive occurrence of FPD.

4.1.11.2. Recommendations

1) Improving the mobility of the birds, providing more space and a good litter quality is recommended to decrease locomotory disorders and prevent FPD and hock burn. It is recommended that breeding programs that put emphasis on selection for better leg health are applied.
2) Feeding programmes should match requirements as indicated by the management guides for the hybrids to promote the mobility of the birds.
3) It is recommended to use slower-growing hybrids that usually have better mobility than fast-growing hybrids, a reduced risk for locomotory disorders and thus show more activity.
4) It is recommended to use environmental enrichments that promote locomotor activity of broilers (e.g. three-dimensional structures).
5) In order to avoid impaired locomotion caused by contact dermatitis, it is recommended to prevent the development of wet litter by improved climate management.
6) It is recommended to use a covered veranda in addition to the barn. The covered veranda should be attractive to the birds thereby encouraging them to use this additional space. Litter should be used in the covered veranda.
7) If good quality litter cannot be maintained, the stocking density should be lowered.
8) Broilers that are lame (gait score 4 or above) need to be placed in a sick pen with easy access to feed and water and with dry litter to allow recovery, or must be culled according to best practices.

4.1.12. Predation Stress

4.1.12.1. Conclusions

1) 'Predation stress' has been identified as a highly relevant welfare consequence for chickens kept for meat production in floor systems with free range and in mobile housing with free range.
2) Predation stress elicits fear in broiler chickens and can lead to distress and to soft tissue lesions and integument damage, resulting in pain. Thus, mortality due to predation can occur in single animals but may sum up in high mortality rates (due to predators repeatedly attacking birds) or piling and smothering of the flock.
3) The ABMs to assess 'predation stress' in broiler chickens are 'mortality due to predation', and 'fear responses'. 'Mortality due to predation' has high sensitivity and high specificity. 'Fear response' is an iceberg indicator that can be used in addition to the ABM 'mortality due to predation'.
4) The most important hazards for predation stress in floor systems with free range and mobile systems with free range are threat by predators, the likelihood of which is higher in case of insufficient fencing, insufficient shelter or vegetation or underdimensioned popholes, the latter impairing the retreat of chickens inside the barn to escape from predators.
5) Predation stress can, to a certain extent, be prevented by providing predator-proof fences, natural shelters such as trees and tall grasses, artificial shelters, large pophole dimensions, and by use of hybrids adapted to free range systems.
6) Corrective measures when predation occurs can be done to a certain extent, by providing artificial shelter or poles with moving objects in case of aerial predation and fencing adapted to terrestrial predation during a production cycle when there is pressure from predation.

4.1.12.2. Recommendations

1) To prevent predation, it is recommended to provide fencing systems for the outdoor range and a closed house during the night against ground predators.
2) With respect to aerial predation, the range should be covered with trees or tall grass, or artificial cover, so that the chickens can seek hide from predators. The outdoor area can also be covered by lines of strings to limit access from above.
3) It is recommended to use specific hybrids with high mobility and performing alarm calls, causing an antipredator reaction in the flock.

4.1.13. Restriction of movement

4.1.13.1. Conclusions

1) 'Restriction of movement' has been identified as a highly relevant welfare consequence for broilers kept on floor indoors, broiler breeders kept in individual cages and in collective cages because they restrict the behaviour the chickens are motivated to perform.
2) The ABMs to assess 'restriction of movement' are 'locomotory behaviour', 'feather and body dirtiness', 'wing flapping', 'footpad dermatitis', 'hock burn', 'wounds', 'walking ability', and 'stereotypic behaviour'. 'Locomotory behaviour' has high sensitivity and low specificity and 'wing flapping' has high sensitivity and low specificity. The other ABMs are considered iceberg indicators which can be used in addition to other ABMs.
3) Restriction of movement can be caused by hazards associated to the housing system such as limited space allowance (high stocking density), limited total size of the enclosure, lack of elevated structures, uncomfortable or inaccessible elevated structures, or bad litter quality (causing lesions to feet and legs).
4) Alternatively, restriction of movement can be caused by locomotory disorders (FPD, hock burn, leg deformations) leading to pain and consequently to difficulties to move (see section 4.1.11).
5) Fast-growing broiler chickens (i.e. growth rate > 50 g/day) usually have a worse mobility and are less able to reach elevated structures and thus experience more restriction of movement than slower-growing broiler chickens (i.e. growth rate < 50 g/day).
6) Measures to prevent restriction of movement in broiler chickens and broiler breeders are avoiding cages, increasing the space allowance per bird, using a slower-growing hybrid

(growth rate < 50 g/day), and providing elevated areas that are comfortable and easily accessible to the birds.
7) In case restriction of movement is present, thinning can be applied to increase the space allowance and mitigate the welfare consequence for the birds that stay in the system.

4.1.13.2. Recommendations

1) To prevent restriction of movement, it is recommended to increase the space available for the individual bird, e.g. by decreasing the density of animals in the barn or increase enclosure size.
2) Adding a covered veranda to increase the available space is recommended. Verandas should be made available from 14 days of age.
3) As the covered veranda to some extent protects the broilers from wild birds/other animals, such a veranda is recommended to avoid restriction of movement in case of high circulation of avian influenza, when the outdoor range cannot be used.
4) Covered verandas with strict hygiene protocols are recommended to be used for broiler breeders.
5) All recommendations to prevent locomotory disorders also apply here, as locomotory disorders are a main reason for restriction of movement.
6) Fresh, dry and friable litter should be provided at all times.
7) When providing perches and platforms, these should be designed in such a way that they are easy to access and comfortable to the broilers, e.g. with a ramp or of adjustable height to enable broilers to access these as the birds are growing. The space allowance will be increased when areas underneath the elevated resting areas are accessible for the animals.
8) Broiler breeders should not be kept in cages, but if they are, the use of cages should be limited to the shortest time possible, and furnished collective cages are preferred over individual unfurnished cages.
9) Furnishing in the cage should be designed to decrease negative welfare consequences for the birds (e.g. more space, perches, nest boxes, litter, visual contact with conspecifics in case of individual cages).

4.1.14. Resting problems

4.1.14.1. Conclusions

1) 'Resting problems' have been identified as a highly relevant welfare consequence in day-old chicks hatched in hatcheries, broiler chickens in all housing systems and broiler breeders kept in cages and floor systems.
2) ABMs identified are the proportion of birds resting and bird disturbances, which both have high sensitivity and specificity.
3) Hatchery procedures, transport and placement in the barn are hazards since they are stressful for day-old chicks and prevent them from proper resting, which may have both short-term and long-term consequences on behaviour and stress.
4) The lack or inaccessibility of elevated structures for resting are hazards for the welfare consequence resting problems in broiler chickens and broiler breeders.
5) Other hazards for resting problems are insufficient space allowance (e.g. in the boxes at the hatcheries or in the barn), disturbances caused by conspecifics, and inappropriate light management, i.e. constant light at high intensities without areas of lower light intensity. Ground or aerial predators can disturb resting when birds are on an outside range.
6) Resting problems in day-old chicks can be prevented by on-farm hatching, where the handling and processing of chicks post-hatch are always reduced and sometimes not even done.
7) Dimming the light intensity during the holding period at the hatchery helps mitigating resting problems.
8) A light regime with a circadian light-dark rhythm stimulates synchronised resting behaviour during the dark period and will thus reduce disturbances of resting birds.
9) In young chicks (< 7 days of age), dark brooders with lower light intensities will support resting behaviour.
10) In broilers of more than 7 days, applying continuous dark periods of 7–8 h per 24 h will help to mitigate resting problems.

11) A reduced stocking density will reduce disturbance of resting chickens with a gradual decrease of disturbance with decreasing stocking density.
12) Use of the outdoor range can be promoted to reduce the indoor stocking density for those birds resting.
13) Providing elevated resting structures, preferably platforms, will reduce disturbances of resting birds and will allow prolonged resting periods.
14) Provision of functional spaces, e.g. by adding dark brooders, panels or bales, elevated structures, reduces the disturbance of resting birds (66–100%). For fast-growing hybrids, 120 cm^2 of brooder space per chick is sufficient for all chicks to fit under the brooders simultaneously until at least 3 weeks of age.
15) Improved access to elevated structures, e.g. due to ramps or adjustable height, will reduce resting problems by supporting the use of the elevated structures.
16) Separating male and female broiler breeders for part of the day can reduce disturbance and alleviate resting problems (50–100%).

4.1.14.2. Recommendations

1) It is recommended to hatch chicks on farm to reduce disturbances and thus resting problems during the first days of life.
2) For broilers chickens and breeders, lowering the stocking density and giving improved access to elevated structures is recommended to reduce the resting problems. For broiler breeders, cage-free systems with accessible aerial perches should be used.
3) Space allowance per bird should be increased as described in the recommendations of the stocking density and functional areas, e.g. dark brooders, panels or bales, should be provided. These measures prevent resting birds from being disturbed by other birds.
4) If dark brooders are used as the only heat source, minimum 120 cm^2 of dark brooder should be provided per chick to ensure enough space for all chicks to use the dark brooders simultaneously.
5) Broilers and broiler breeders should be offered a light-dark schedule. In broilers until 3 days of age, continuous light can be offered in combination with lower light intensities under dark brooders. After a gradual decrease of the photoperiod, starting at 7 days of age, broilers should be provided with continuous dark periods of 7–8 h per 24 h.
6) A gradual increase and decrease in light intensity at the start and end of the daylight (dawn and dusk) should be used, as it allows the birds to find proper roosting spaces and smoothens the transition between rest and activity.
7) For broilers with outdoor access, fencing systems and a closed house during the night should be used to avoid that resting problems occur due to ground predators.

4.1.15. Group stress

4.1.15.1. Conclusions

1) All categories of broilers housed in groups can experience group stress, but it is only identified as a highly relevant welfare consequence when the birds are reared until the beginning of sexual development (onset of puberty) or beyond. Therefore, group stress has been identified as highly relevant welfare consequence for chickens for meat production kept in floor systems with veranda and outdoor access (slower-growing) as well as broiler breeders kept on floor and in multi-tier systems.
2) Group stress is caused by social and/or non-social factors (e.g. predation stress). Social factors such as severe/injurious pecking will increase stress and thus the risk of increased occurrence of abnormal behaviours.
3) Group stress leads to distressed and nervous birds which in turn can show abnormal behaviours, e.g. injurious pecking, leading to additional welfare consequences, further reducing welfare.
4) ABMs identified are 'flock activity', 'fear response' (e.g. in standardised test), 'plumage damage', 'injurious pecking' and/or the 'number of aggressive interactions' and 'piling and smothering'. 'Fear response', 'plumage damage', and 'piling and smothering' are considered iceberg indicators and can be used in addition to other ABMs.
5) Hazards leading to group stress will, in general, be associated with space allowance per bird and underdimensioned resources (e.g. feed space or pophole size for free-ranging birds)

will increase negative interactions between birds and, therefore, lead to group stress. Some slower-growing hybrids are prone to show more aggressive interactions than fast-growing hybrids.

6) Functional areas, including elevated platforms, panels will help the bird to prevent social stress.
7) Any reduction in stocking density will in turn reduce the risk of negative inter-individual contacts leading to group stress.

4.1.15.2. Recommendations

1) In case broilers are kept until sexual maturity or beyond, special measures should be applied to avoid group stress.
2) To mitigate social stress stocking density should be lowered, also within an ongoing production period by thinning.
3) Three-dimensional structures should be provided to broilers to increase the space allowance per individual and enable the animals to use different functional areas and allowing them to escape from other birds, when needed.
4) A covered veranda should be provided to allow decreasing the stocking density both inside the barn and in the veranda, which gives more opportunity for the birds to increase inter-individual distances.
5) In addition to a covered veranda, adequately structured and enriched free range should be provided to encourage even a more homogeneous distribution of the flock, decreasing local stocking densities.
6) Selection of low aggressive hybrids is possible and should be applied.

4.1.16. Soft tissue lesions and integument damage

4.1.16.1. Conclusions

1) 'Soft tissue lesions and integument damage' have been identified as highly relevant welfare consequence for broilers kept in all floor systems (the exception being the mobile free-range system), and for broiler breeders kept in all systems.
2) FPD and hock burns are the most common soft tissue health-related problems in broiler chickens, although cellulitis, scratches on the back of the birds and irritation, inflammation and blisters on the breast also occur. Feather damage is seen more in slower-growing hybrids than in fast-growing. Injurious pecking has a genetic component. In broiler breeders, wounds on the back and neck of the females kept in mixed sex groups are common and there can be damage to the feet of birds kept in cages. Mutilations such as beak trimming and toe clipping are common practices in breeders in many countries
3) ABMs include the presence of 'wounds', 'breast blisters' and 'breast burn', 'bruises', 'cellulitis', 'FPD', 'plumage damage', 'hock burn' and 'injurious pecking'. 'Breast blisters', 'breast burns', 'bruises' and 'cellulitis' have a low sensitivity (since they detect only one aspect of soft tissue lesion) and high specificity. 'Wounds', 'plumage damage', 'FPD', 'hock burn' and 'injurious pecking' are considered iceberg indicators and can be used in addition to other ABMs.
4) Poor quality litter is a main hazard for FPD, hock burn and breast lesions. Exposure to the outdoor climate in free range can make it more difficult to maintain the litter dry and friable inside the house. Low space allowance is also a main hazard for FPD, hock burns and breast lesions, as well as for scratches on the back of the birds. In addition, lack of elevated areas (through the link to space allowance on the litter) is a hazard for broilers and broiler breeders for soft tissue and integument damage.
5) Flight reactions can result in wounds and bruises.
6) Wounds in female breeders are often caused by males because of frequent mating or mating attempts in breeding flocks.
7) Preventive measures include a reduction of the stocking density in the building, which makes it easier to maintain good litter quality and prevent contact dermatitis and lesions.
8) Wounds to the beak and feet of birds can be prevented by not performing routine beak trimming, toe clipping and de-spurring. Once these mutilations are performed, there are no corrective or mitigative measures.

9) A mitigative measure to improve litter quality, and so limit the further development of FPD or other forms of contact dermatitis, is to replace wet or caked litter with new friable litter or to add additional new litter.
10) Separating male from female broiler breeders for part of the day will reduce wounds, as this will allow females to escape, e.g. to elevated areas or behind partitions.

4.1.16.2. Recommendations

1) The litter should be maintained dry and friable in the barn and the covered veranda to reduce FPD, hock burns and breast blisters in broiler chickens and breeders.
2) Any type of disturbances that result in flight responses where birds may be injured, e.g. a sudden loud noise, should be avoided.
3) It is recommended that breeding programmes should focus on minimising injurious pecking behaviour, thereby decreasing the risk of damage to feathers and tissue, and consequentially phase out the need to beak-trim birds.
4) To reduce wounds made to the females by the males during mating or mating attempts, it is recommended: (1) to maintain the male/female ratio between 1/10 and 1/12, (2) to offer places of retreat to females, (3) to include in the selection programme the minimisation of aggressive mating behaviour, (4) to limit spiking with younger males. These measures will also reduce the need to toe clip or de-spur males.
5) The use of attractive outdoor areas (see section 3.5.1.9), thereby promoting the use of these areas by the birds, is recommended.
6) A transition area, where dirt on the feet of the broilers will be removed while they pass by before they enter the building, can help reduce water or mud being transferred into the house from the free-range area, helping to preserve litter quality. Popholes should be of an appropriate size and designed in a way that limits the flow of humid air into the housing system.
7) It is recommended to rear broiler chickens and breeders with access to elevated structures from day-one, so that birds develop good spatial skills and are less likely to be injured when moving in the system.
8) To avoid the types of foot damage that result from standing on a wire floor for prolonged periods of time, it is recommended that there is always litter available to broiler breeders.

4.1.17. Umbilical disorders

4.1.17.1. Conclusions

1) ‘Umbilical disorders’ have been identified as highly relevant welfare consequences in day-old chicks.
2) Unhealed navels can be a source of infection and compromise the welfare of the chicks as the condition may cause discomfort and pain and potentially result in mortality.
3) The ABM identified is a clinical examination of the navel of day-old chicks. The ABM ‘navel condition’ has high sensitivity and high specificity.This can be done systematically by using one of the qualitative methods used to assess chick quality, such as the Pasgar and Tona scores. This ABM is highly sensitive and highly specific.
4) Eggshell temperature higher than 37.8°C during incubation, particularly during the last week before hatching may lead to increased prevalence of unhealed navels.
5) Proper management of day-old chicks with unhealed navels (i.e. either culling or placement in sick pens with extra monitoring/surveillance) mitigates the potential suffering of undiscovered chicks with severe umbilical disorders.

4.1.17.2. Recommendations

1) To prevent umbilical disorders, eggshell temperature during incubation should not exceed 37.8°C, and this should be monitored automatically in the hatchery, during transport of incubated eggs and during the hatching period on the farm.
2) To minimise the prevalence of chicks hatching with unhealed navels, sorting out these chicks before placement is fundamental.
3) Depending on the degree of healing, either culling by following the best practice methods or placement in sick pens with extra surveillance is recommended for chicks experiencing unhealed navel.

4.1.18. Inability to avoid unwanted sexual behaviour

4.1.18.1. Conclusions

1) Broiler breeder males have been selected for mating activity. Therefore, when possible, they frequently perform copulatory behaviour, and it can be forceful. Consequently, females try to avoid the males but are not always successful. Therefore, the 'inability to avoid unwanted sexual behaviour' has been identified as highly relevant for female broiler breeders housed in any system except in individual cages.
2) Rough mating will increase the severity of this welfare consequence compared to gentle mating.
3) ABMs include 'forced copulations', 'avoidance of the litter by the females', 'wounds' and 'plumage damage'. 'Forced copulations' is highly sensitive and specific. The 'avoidance of the litter area by the females' is moderately sensitive and specific. 'Wounds' and 'plumage damage' are considered iceberg indicators and can be used in addition to the other ABMs.
4) In most current housing systems like collective cages and floor housing, females hardly have any possibility to avoid forced mating.
5) Males are mutilated (de-toed, beak trimmed) to avoid wounding the females during forced copulations, but mutilation causes welfare consequences to males.
6) In multi-tier systems or systems with perches, females have a better possibility to avoid unwanted sexual behaviour than in furnished cages or floor systems, but this mitigating potential is limited because males copulate with females also on tiers and have been observed pulling them from perches to mate.
7) A too high male to female ratio and spiking, the replacement of males by younger males during the production cycle, are hazards for inability to avoid unwanted sexual behaviour.
8) In addition, genetic selection against too frequent and rough mating can mitigate or even prevent the welfare consequence.

4.1.18.2. Recommendations

1) Males should not be selected based on their frequent copulatory behaviour.
2) Elevated structures like perches, raised slats, or cover panels can be offered where females to some extent can escape the males or, alternatively, sexes could be separated during part of the day.
3) Males and female broiler breeders should be raised separately until they are both sexually mature. Spiking should be prevented.
4) Another mitigative measure can be the reduction of number of males (lower ratio of males/ females than 1/10).

4.1.19. Sensory under and/or overstimulation

4.1.19.1. Conclusions

1) All categories of birds can experience sensory over- and/or understimulation, especially in barren environments, and this WC has been identified as highly relevant for day-old chicks, irrespectively of where they are hatched.
2) ABMs for under and overstimulation are vocalisations of the animals ('distress calls'), 'fear response', 'altered resting behaviour' and 'piling and smothering'. These ABMs are iceberg indicators.
3) Identified hazards are sudden noises resulting in panic responses and lack of a diurnal light/dark schedule during incubation (in the hatchery or on-farm) and the first days after placement in the barn.
4) Sensory overstimulation can be prevented by applying a light-dark schedule upon placement of the eggs in the incubator, hatcher and/or barn, a heterogeneous light distribution in the barn or dark brooders. For fast-growing hybrids, 120 cm^2 of brooder space per chick is sufficient for all chicks to fit under the brooders simultaneously until at least 3 weeks of age. As sudden noises may appear unexpectedly, corrective or mitigative measure are not available, except that the noise should be stopped as soon as possible.
5) Understimulation can be mitigated by environmental enrichment.

4.1.19.2. Recommendations

1) For the prevention of under- and/or overstimulation, management guides should be followed as these give information on light regime, handling, etc.
2) It is recommended to have a brooding light program (alternating light and dark periods) or a dark area such as brooders for chickens until 14 days of age to prevent overstimulation.
3) If dark brooders are used as the only heat source, minimum 120 cm^2 of dark brooder should be provided per chick to ensure enough space for all chicks to use the dark brooders simultaneously.
4) Functional areas should be established by the use of different light intensity. High intensity promotes activity and low intensity allows for resting. Light flicker frequency as well as light composition should meet the chickens' needs.
5) More research is needed for the implementation of functional light zones based on a heterogeneous light distribution in the barn (e.g. brighter at feeder/drinker, darker in heated zones).
6) Avoiding sudden noises, visual or any sensorial overstimulation is recommended.

4.2. Answers to specific ToRs

4.2.1. Enclosure requirements in broiler production (broiler breeders, broiler chickens (fast- and slower-growing))

4.2.1.1. Management

Stocking density (Specific ToR 1c)

Conclusions

The stocking density recommended below applies under the assumption that all other factors are as described in the minimal enclosure section.

The two EKEs and the behavioural space model yielded comparable median stocking densities ranging from 10 kg/m^2 to 12 kg/m^2. Based on these results, it is concluded that a maximum stocking density of 11 kg/m^2 will prevent the welfare consequences 'restriction of movement', 'inability to perform exploratory and foraging behaviour', 'inability to perform comfort behaviour' and 'soft tissue and integument damage' (66–100% certainty). Any further reduction of the stocking density will lead to an increase in the certainty that the highly relevant welfare consequences mentioned above will be prevented.

Recommendations

A maximum stocking density of 11 kg/m^2 for fast-growing broiler chickens is recommended to prevent the welfare consequences identified as highly relevant.

Minimal height at any point

Conclusion

There is a lack of accurate measurements of the vertical space needed of fast and slower-growing broilers and broiler breeders when performing different behaviours. It is concluded (66–100% certainty) that the minimum vertical space needed for a broiler chicken to avoid 'restriction of movement' and 'inability to perform comfort behaviour' is 55 cm. It is concluded (66–100% certainty) that the minimum vertical space needed for a broiler breeder and for slower-growing broilers to avoid 'restriction of movement' and 'inability to perform comfort behaviour' is 77 cm.

Recommendation

Any part of the system that is included in the calculation of 'usable area' should be at least 55 cm high for fast-growing broilers and at least 77 cm high for slower-growing broilers and for broiler breeders.

Minimum usable area

Conclusions

When determining the minimum usable area, many factors are at play (e.g. enrichment, group size, stocking density) and thus may influence the minimum area required by the chickens. If enrichment items like panels are used, their area can be added to the floor area as broilers make use of both.

In addition, the minimum indoor usable area depends on the bird category. For fast-growing broilers it is 23 m^2 (> 50–100% certainty), for slower-growing broilers 29 m^2 (> 50–100% certainty), and for broiler breeders 80 m^2 (66–100% certainty).

In breeders, the welfare consequence 'inability to avoid unwanted sexual behaviour' can to some extent be prevented by addition of structures like panels and perches which requires that the birds have access to an enclosure large enough to allow the provision of these structures.

Recommendations

The minimum indoor usable area depends on the bird category. Pen size for fast-growing broilers should have a minimum of 23 m^2, slower-growing broilers should have 29 m^2, and broiler breeders should have 80 m^2 available. These are the minimum usable area figures recommended with the stocking density up to 11 kg/m^2.

Enrichment like panels and perches should be provided to motivate birds to use the entire enclosure.

Panels and perches are especially important in broiler breeder floor housing for the females to avoid to some extent unwanted sexual behaviour.

Light

Conclusion

Light intensities of at least 20 lux were found to support activity and, therefore, welfare in broilers (66–100% certainty). The intensity might be as low as 0.5 lux in resting areas (66–100% certainty). A spectrum based on daylight and including UV light allows the broilers to express their natural behaviour. The threshold for the flicker frequency was found to be 95 Hz. After an initial continuous lighting of up to 23 h during the first three days of life, a light period of 16–17 h and an uninterrupted dark period of 7–8 h supports the expression of welfare-related behaviours. Limited evidence was found supporting functional areas illuminated with different intensities and/or spectra. When a veranda is not available for the birds, animals should have access to natural light in the barn.

Recommendation

The environment should be illuminated at 20 lux minimum, with functional areas of resting (e.g. dark brooders) offering intensities down to 0.5 lux. To allow all chicks to use the dark brooders simultaneously, minimum 120 cm^2 of dark brooder should be provided per chick to ensure enough space. Chicks should be provided with 23 h light up to day 3 of life with a gradual decrease of the photoperiod to 16–17 h at day 7. The light spectrum should be a near-natural day light including UV. Flicker frequency should be above 95 Hz. Instead of uniform housing, broilers might benefit from functional areas providing different light intensities and spectra (e.g. covered veranda). More research should be carried out on the effect of light schedules and functional light areas on broiler welfare.

Temperature (Specific ToR 1a)

Conclusion

Day-old chicks are at risk of cold stress when they experience effective temperatures below 30°C.

For chickens with an age of 27 days and older, there is a risk of cold stress at effective temperatures below 17°C, although the exact threshold is dependent on factors such as age, hybrid, humidity, air speed, body weight, stocking density, degree of adaptation and duration of exposure.

Broiler chickens in mobile systems are at risk of heat stress during summer when outdoor temperatures are high. The threshold for heat stress is dependent on many factors such as age, hybrid, humidity, wind speed, body weight, stocking density, degree of adaptation and duration of exposure.

Slower-growing chickens are less at risk of heat stress than fast-growing chickens.

It is assumed that broilers are able to cope with short periods of heat and cold by adapting their behaviour so that their core body temperature is not affected.

Recommendation

At placement and in the first week of life, chicks should be offered an effective air temperature of 30–35°C and a floor temperature of 28–30°C to spare them from cold stress.

The minimal temperature should gradually be decreased to 17–21°C for chickens of 27 days or older. As cold stress is prevented by proper plumage, the threshold for experiencing cold stress depends on the hybrid or parent housed. Slower-growing broilers and breeders may be exposed to lower temperatures depending on the time interval of exposure and whether the birds have the choice to choose between thermal zones, with warmer ones.

In mobile systems during hot weather conditions, the house should be placed in such a way that the risk of heat stress is minimised and its efficiency can be measured by the ABM ‘panting’. In addition, sufficient natural shelter from solar radiation should be available in the outdoor range.

In mobile systems during winter, the indoor area should be equipped with heating.

Air Quality and dust (specific ToR 1d)

Conclusion

Specific gases of the barn air might be harmful for chickens as well as for humans. Ammonia and CO_2 are the gases present in broiler barns that may impair bird welfare. Ammonia levels beyond 15 ppm impair welfare of broiler chickens (66–100% certainty). For dust, no specific levels have been found regarding bird welfare on farm. In Europe recommendations of CO_2 rate below 3000 ppm are applied and expert judgement did not identify any welfare impairment linked to CO_2 concentration below 3000 ppm. No harm was observed in the lungs of broilers exposed to 5000 ppm of CO_2.

Recommendation

Active (forced) ventilation systems should be used to reduce the build-up of harmful gases and ensure good air quality. In addition, a good litter management, including the provision of new low-dust litter substrate, will support litter quality and reduce emissions. Also floor heating to reduce humidity or raised platforms with integrated manure belts, which allow manure removal, should be used in broiler and breeder housing. Ammonia levels should be kept below 15 ppm. More research is needed to determine the maximal CO_2 and dust concentrations preventing negative welfare consequences.

Group size

Conclusion

Minimal group size of 2 birds prevents isolation stress. Research on the effect of group size is needed to determine a maximum group size. With the available scientific evidence, it is not possible to define a maximum group size below which the negative welfare consequences will be prevented.

Since slower-growing broilers are slaughtered after sexual maturity, knowledge about maximum group size of these birds is even more important in terms of welfare than for fast-growing hybrids. For both types of hybrids, as well as for their breeders, this constitutes a gap in knowledge.

The male to female ratio should be carefully considered in broiler breeders. Breeding companies usually recommend 1 male per 10 females.

Recommendation

More research should be conducted on the impact of the group size on welfare for fast-growing and slower growing hybrids. Minimal group size is two animals.

If occurrence of unwanted sexual behaviour is rising, the ratio male to females should be decrease below 1:10 to avoid overmating.

Covered veranda

Conclusion

A covered veranda of 20% of the indoor useable floor area (not included in the usable area) will benefit welfare of both broilers and broiler breeders as it provides choice for different light and temperature conditions and provides more opportunities to perform natural behaviour as compared to indoor housing only. Popholes at a maximum height of 25 cm will allow the broilers to access the covered veranda and ramps to the popholes will facilitate this. Enrichment materials such as straw or lucerne bales and foraging and pecking materials will render the covered veranda more attractive for broilers and stimulate the use of it. The birds should be able to access the covered veranda during daytime from at least 14 days of age and onwards (66–100% certainty).

Recommendation

Access to a covered veranda should be provided from 14 days of age onwards for at least 8 h per day with daylight periods of 8 h and longer, or during the daylight period in countries and/or seasons with shorter daylight periods. Popholes should be at a maximum height of 25 cm and ramps should be provided to access the popholes. Enrichment such as straw bales or lucerne bales, foraging materials and other pecking materials should be provided. One longer side of the veranda should be open (with grid or net on all the eight) and should let enter the natural light.

Regarding broiler breeders, requirements of layers can be adopted (EFSA AHAW Panel, 2023). If for any reason no covered veranda can be provided, 20% additional space should be provided indoors (with reference to the minimum space allowance).

Outdoor range

Conclusion

An outdoor area is advised on the condition that it goes together with a covered veranda, as it will benefit broiler welfare. The outdoor range can be accessible from 21 days of age (66–100% certainty) at the latest during daytime.

Offering a covered veranda between indoor housing facilities and outdoor range improves the ranging behaviour of the broilers.

Practical experiences with large areas of vegetation (70% of the range surface) with majority of bushes and trees (50% of the range surface) show that these support the usage of the outdoor area by the birds (66–100% certainty).

A well-designed outdoor range with dense natural cover evenly distributed over the range is attractive to chickens and promotes natural behaviour. Slower-growing broiler chickens are better adapted to make use of the outdoor range than fast-growing broiler chickens, however, an outdoor range may also be beneficial for the welfare of fast-growing broilers and broiler breeders.

Recommendation

An outdoor range accessible from 21 days of age onwards is recommended for fast-growing broilers and broiler breeders and highly recommended to slower-growing broilers.

A transition zone between the indoor barn and outdoor area in the form of a covered veranda or similar is strongly recommended. The range should be accessible during daytime and sufficient natural cover should be present (50% being covered by high vegetation, e.g. bushes and trees and 70% green vegetation in total). Vegetation used in the outdoor range needs to be adapted to the temperatures of the region. If 70% of green vegetation cover cannot be achieved due to climatic conditions, structures that provide shelter and foraging and pecking material should be provided. Vegetation or manipulable material should be evenly spread in the outdoor area.

4.2.1.2. Equipment

Tiers/platforms

Conclusion

Elevated platforms decrease the risk of locomotory problems in broilers and are used better than perches by both fast- and slower-growing broilers.

Addition of an elevated area corresponding to at least 10% of the floor area will reduce resting problems and restriction of movements (66–100% certainty).

A ramp with a maximal angle of 25° will enable the broilers to access the platforms (66–100% certainty).

Elevated platforms will decrease the welfare consequence 'resting problems', 'restriction of movements', 'inability to perform exploratory and foraging behaviour'.

For broiler breeders which are less agile than laying hens, aviaries with multiple tiers can be used (floor plus up to three levels). Aviaries adapted to broiler breeders (not as high as for laying hens) should be used. Platforms with slatted areas can be used.

Recommendation

To reduce resting problem, elevated platforms representing at least 10% of the usable area should be provided. As the use of perches by broilers is limited, at least 10% of the usable area should be covered with elevated platforms and should be accessible by ramps with a maximum slope of 25 degrees. For broiler breeders, both perches and elevated platforms should be offered for resting and night-time roosting, e.g. offering an aviary that is adapted for broiler breeders by being lower than for laying hens with maximally 3 tiers.

Elevated platforms for slower-growing and fast-growing broilers are recommended, and two levels above the floor can be offered for the slower-growing broilers.

More research is needed to estimate the minimal space that is required for elevated platforms for preventing the resting problems in broilers.

Perches

Conclusion

Broiler breeders use elevated perches for resting during the day but especially during night-time roosting which is comparable to laying hens.

A minimum length of 15 cm per breeder is sufficient to ensure that all birds have access to perches (66–100% certainty). A length of 21 cm per hen and 22 cm per rooster ensures that all breeders have access to perches.

Research is missing on the preferred material, shape, and diameter of perches for breeders.

Recommendations

Elevated perches should be offered for resting and night-time roosting.

The minimum length of the perches should be 21 cm for female and 22 cm per male breeder to ensure that all birds can perch at the same time during the night.

More research is necessary about the preferred material, shape, and diameter, so no recommendations about these factors can be given.

Litter

Conclusion

Broilers and broiler breeders need dry and friable litter to meet the behavioural need of scratching during foraging, and dustbathing for that 100% of the floor of the barn (except the platforms) has to be covered at all times with litter that is accessible, dry, and friable before the chicks are placed.

Dry litter is also important to absorb the moisture from the faeces and prevents contact dermatitis like hock burn and FPD.

Permanent access of all birds to dry and friable litter at all times, will allow the broiler to meet its behavioural needs. Rescattering of additional fresh litter after week 2 may be necessary (90–100% certainty).

The provision of new litter stimulates the birds to be active showing its natural behaviour.

Recommendation

In order to give access to litter to all animals at all times, 100% of the floor area of the barn should be covered with litter that is dry and friable and accessible from day one.

Additional new litter should be spread weekly in the barn to cover all the surface of the usable area after week number 2.

The effectiveness of these measures can be assessed by measuring the FPD score.

Nests for breeders

Conclusions

Nesting is a highly motivated behaviour so it is important to female breeders to have access to nests that are attractive to them, and which allow them to perform nest building behaviour. Most work on nesting behaviour has been done on laying hens, but the findings also apply to broiler breeders. That means the same or similar requirements for nests should apply to broiler breeders and there is no evidence to recommend something different from the industry recommendations.

Recommendations

Any enclosure, where adult female broiler breeders are kept, should contain one or more separate areas destined for egg laying. Nests should satisfy the following requirements: A nest should have an opaque top, sides and back to achieve a secluded, safe atmosphere for the egg-laying bird. The front should be furnished with an opaque curtain that birds can easily pass through to enter the nest. The floor should not be of wire mesh, and it should contain manipulable material for nest building. Nests can be dimensioned to allow a single bird to show nesting behaviour or of a size that allows a small group of laying birds to nest together. Access to nests should be facilitated by the installation of platforms rather than perches in front of the nest entrances. There is no evidence to recommend a specific number of nests per broiler breeder that is different from the current industry practice (e.g. 3.5–4 hens per nest hole for manual nests or 40 hens per linear meter communal nests).

Feeders

Conclusions

Since broiler breeders are kept on a restricted diet, it is important that they can all access the feed when provided. This is possible when spin feeders are used, but when a feed trough or pan feeders are used, the space allocation should not be less than the width of the bird. Thus, space at a pan feeder of at least 11 cm for females and 13 cm for males and 21 cm for females and 22 cm for males at a straight feed trough will allow all birds to access at the same time for breeders (66–100% certainty). Feed is more freely available for broilers kept for meat production, so it is not necessary to provide space equivalent to their body width at the feeder, but too small allocation results in increased competition and aggression. Circular pan feeders of at least 4.5 cm per bird for both fast and slower-growing broilers allows birds to access the food simultaneously (66–100% certainty). Given the reduced locomotory activity of broilers, it is important that feeders are evenly distributed in the house.

Recommendations

For broilers kept for meat production the minimum feeding space at a pan feeder should be 4.5 cm and feeders should be evenly distributed throughout the system. For breeding birds feeding from a straight feed trough, it should be 21 cm for females and 22 cm for males. For breeding birds feeding from a round trough, the recommendation is 11 cm for females and 13 cm for males. The use of spin feeders, especially for broiler breeders should be considered since it avoids competition at the feed trough by redirecting feeding behaviour to the litter.

Drinkers

Conclusions

Access to water is needed to prevent 'prolonged thirst' for all categories of birds. Water intake is affected by many factors, so it is difficult to draw conclusions about the exact drinker space required. Current recommendations for drinker space for preventing 'prolonged thirst' seem appropriate, corresponding to a maximum of 10 birds per nipple drinker (66–100% certainty).

Recommendations

Water should be easy to access and available at all times. Each bird should have access to at least two sources of water and a maximum of 10 birds per nipple drinker is recommended. The height of the drinkers should be adapted to the age of the birds and so that small or lame birds can reach them at all times. Drinkers should be evenly distributed in the building.

Enrichment

Conclusions

Environmental enrichment such as perches, platforms, or other structures, litter suitable for dustbathing, and access to outdoor areas encourage broilers and breeders to be active and lower the risk for locomotory disorders.

Dry, friable litter and additional foraging material enables broilers and breeders to perform exploratory or foraging behaviour and litter with small particle size stimulates dust-bathing behaviour.

The permanent provision of enrichment and foraging material prevents the negative welfare consequences 'inability to perform exploratory or foraging behaviour' (and then help preventing other welfare consequence such as 'group stress' and 'soft tissue lesions and integument damage') for broiler chickens and breeders.

Recommendations

Enrichment substrate in addition to litter should be accessible at all times from day 1 to all broilers. Small particle size substrate is recommended for dustbathing, e.g. sand-like or peat-like substances but not faecal material. The dustbathing material should be added in addition to the litter unless the litter consists of small particles. Any enrichment material should be renewed before it is depleted.

4.2.2. Feed restriction in broiler breeders (specific ToRs 3b)

4.2.2.1. Conclusions

Any practiced form of feed restriction causes 'prolonged hunger' in broiler breeders shown by the ABMs, stereotypic behaviours as an indicator of feeding motivation and polydypsia.

1) The level of feed restriction is dependent on the production stage, being more severe during rearing, i.e. before sexual maturity, and less severe during the egg production period for females.
2) No currently known practice to mitigate hunger while controlling body weight in feed restricted broiler breeders can alleviate 100% of the hunger.
3) The higher the restriction of growth that is targeted and thus feed restriction, the greater the level of hunger.
4) The more the selection on fast growth rate in the broilers, the higher the growth potential in the broiler breeders, and the more severe the consequences of feed restriction will be, and this will continue if genetic selection does not change.
5) The feeding motivation, which is an indication for 'prolonged hunger', is reduced if the feed restriction is relaxed in general or at certain periods during rearing and early lay.
6) There are slower-growing hybrids available, partly with dwarfed females, that do not need to be feed restricted during the laying period, and thus will prevent the negative welfare consequence linked with feed restriction, at least during the production period. Hence, in this aspect slower-growing hybrids requiring less restriction have higher welfare than fast-growing hybrids.
7) The addition of at least 10% insoluble fibres in commercial feed reduces hunger (certainty 66–100%) without having negative impact on other welfare consequences.
8) The addition of soluble fibre will reduce hunger (certainty 50–100%). However, the addition of soluble fibres can impair welfare by leading to malaise and discomfort in birds, as well as to watery faeces and downgraded litter causing additional negative welfare consequences (certainty 66–100%).
9) The use of calcium propionate in the feed induces negative affective states in broiler breeders due to discomfort (certainty 66–100%).
10) The combination of different mitigation measures will reduce the experience of hunger (e.g. slower-growing hybrids in combination with diluted diets and relaxed feed restriction) (certainty 66–100%, depending on the mitigation measures).
11) If the diet is balanced in terms of daily requirement of amino acids, then the protein content can be decreased by 15–25% of the original protein content in the diet without impairing animal welfare (certainty 66–100%). Reducing the protein content in the feed is another method to reduce the energy level, and thereby allows the birds to consume an increased amount of feed, potentially reducing hunger. However, the available knowledge does not allow for a recommendation of a specific level of reduction of the protein content that will ensure reduced hunger and improved animal welfare. This constitutes a gap in knowledge.
12) There are different methods to prolong the time eating (e.g. scatter feeding and providing mashed feed), and thereby decrease the duration of feeling hungry (66–100% certainty).
13) There is controversial evidence whether non-daily skip a day feeding schedules mitigate the feeling of hunger (compared to the same about of feed distributed daily) but there is increasing evidence that non-daily feeding schedules have a negative effect on health and production.
14) Only prototypes using Precision Livestock Farming (meaning automated technology) techniques of individually adjusted feeding portions exist and little is known about the technology on farms. The available knowledge does not allow any conclusion to be drawn. The frustration created by the presence of the feed stimuli might negatively impact the bird experiencing hunger, but more research is needed.

4.2.2.2. Recommendations

1) The use of slower-growing hybrids and selection of new hybrids that are less feed restricted than the currently used hybrids is strongly recommended. The selection for even faster and more efficient growth rates must be avoided.
2) It is recommended to relax the feed restriction by providing at least 10% more feed compared to the current recommendation in the guidelines.
3) The level and timing (length) of feed restriction should be more focused on the welfare of the birds than on the minimum amount of feed necessary to maximise production while having the lowest possible feed costs.
4) Although no previously known mitigative measure of changing the feed composition has proven to effectively prevent 'prolonged hunger', measures like diluting the diet by adding insoluble fibres (at least 10%) and reducing the protein content by 25%, as well as optimising the frequency of feedings and the presentation of feed should be pursued, ideally in combination.

5) Soluble fibres should not be added to feed.
6) Appetite suppressants like calcium propionate should not be added to the diet because birds may find this substance aversive and thus the addition would lead to reduced welfare.
7) It is recommended to combine different mitigation measures as this is expected to reduce the hunger imposed by feed restriction to a greater extent than using a single measure.
8) Further research is necessary to understand the effect of precision feeding.
9) Skip a day feeding is not recommended currently due to the negative impact on health and production, despite some contradictory research results.

4.2.3. Housing in individual cages (specific ToR 3a)

4.2.3.1. Conclusion

Keeping chickens in single cages leads to severe welfare consequences that cannot be prevented in this housing system. The severity of some of the welfare consequences may be mitigated by enlarging the space and adding furnishings like perches and nest boxes. However, even in this case the isolation from other birds leads to impaired welfare.

4.2.3.2. Recommendations

It is recommended that (single) cages are not used.

4.2.4. Mutilations of broiler breeders (specific ToR 3b)

4.2.4.1. Conclusion

Mutilations are associated with pain. There is a good level of knowledge about the pain and long-term effects associated with the most commonly performed types of mutilation in broiler breeders, i.e. beak trimming and toe clipping, as well as how to prevent, correct and mitigate the behavioural problems the mutilations were originally intended to reduce. Furthermore, there are examples of farms, and even countries, where broiler breeders are managed successfully without mutilation.

4.2.4.2. Recommendation

All preventive methods should be in place to avoid welfare consequences that could appear when mutilation is not performed. All forms of mutilations should be avoided in broiler breeders.

4.2.5. Access to feed and water (Specific ToR 1b)

4.2.5.1. Conclusions

1) A delay of access to first feed and water in day old chicks of more than 48 h (range 36–60 h; from hatching to access to feed and water at placement) may lead to prolonged hunger and thirst.
2) Regarding chickens older than 7 days, very small chickens ('runts') and chickens with walking impairment (gait score of 4 or higher) experience prolonged hunger and thirst as they are unable to reach (sufficiently) the feeders and drinkers.

4.2.5.2. Recommendations

1) Feeding in the hatchery or on-farm hatching should be applied as it prevents hunger and thirst in day-old chickens.
2) The minimum barn temperature should be 30°C and the minimum floor temperature 28°C to prevent cold stress in day-old chicks and to stimulate them to find feed and water.
3) Farmers should carry out frequent checks (every 3–4 h during the first days) to ensure that chicks have found food and water.

4.2.6. Welfare of Day-Old-Chicks until they reach the rearing or breeding farms: hazards under hatchery conditions (specific ToR 4)

4.2.6.1. Conclusions

During early life, i.e. the period from hatch to right before being loaded for transport to the rearing barn, broiler and broiler breeder chicks are exposed to several practices that are perceived as stressful and have been shown to have either short-term or both short-term and long-term detrimental effects on the welfare of the chicks. See sections 4.1.7 for detailed conclusions on prolonged hunger and

4.1.8 for conclusions on prolonged thirst. See sections for conclusions on sensory under and/or overstimulation and 4.1.9 for conclusions on handling stress.

4.2.6.2. Recommendations

Initiatives should be taken to prevent, correct or mitigate some of the negative impact on the chicks' welfare imposed by the traditional practices. It is recommended to:

1) Apply a light programme consisting of 12 h/12 h (light/darkness) during incubation of the eggs to avoid understimulation.
2) Hatch chicks on farm with immediate access to feed and water to prevent prolonged hunger and thirst and to reduce bird disturbances to mitigate resting problems.
3) Keep the time between hatching and placement as short as possible and no more than 48 h post-hatch to reduce prolonged hunger and thirst.
4) Keep handling time as short as possible to reduce handling stress.
5) Avoid changes in velocity on conveyor belts greater than 0.4 m/sec, drop heights above 280 mm and speeds of $\geq$ 27 m/min to reduce handling stress.
6) Train staff in proper handling and surveillance of the system to minimise handling stress.
7) Use both hands to support the full body during handling to minimise handling stress.

4.2.7. The assessment of Animal Based Measures collected in slaughterhouses to monitor the level of welfare on broiler chickens farms (specific ToR 2)

4.2.7.1. Conclusions

1) 'Total mortality', 'proportion of birds with wounds', 'carcass condemnation' and 'footpad dermatitis' are the most promising ABMs for collection at slaughterhouses to monitor the level of welfare on farm for broilers.
2) The welfare consequences on farm assessed through the ABMs collected at the slaughterhouse may be an underestimate of the welfare consequences on farms, as not all welfare consequences are identified and animals with severe welfare consequences will not be sent to the slaughterhouse. The presence of these ABMs identifies possible welfare problems, but their absence does not mean that no welfare issues exist.
3) Validated methods (i.e. that the method is linked to the animal welfare) to assess FPD exist and are used routinely at slaughter in some countries. However, there is a lot of variation in the methods used for measuring each ABM and only few of them are tested for reliability and validity. Uniform and standardised scoring systems and protocols across different regions/member states are necessary to monitor and benchmark the welfare of broilers.
4) The Technology Readiness Level (TRL) of automated monitoring of the ABMs at slaughterhouse is variable between the proposed ABMs. 'FPD' is the most advanced followed by 'carcass condemnation' and 'wounds'.

4.2.7.2. Recommendations

1) Monitoring 'mortality on farm', proportion of birds with 'wounds', 'carcass condemnation' and 'footpad dermatitis' in broilers at slaughter should be implemented to identify flocks of broilers with diverse welfare consequences, allowing targeted inspection and establishment of preventive methods for the next flocks.
2) The cumulative daily mortality rate and cumulative daily culled rate should be calculated for each week of the production cycle together with the rates at the time of slaughter to provide information on the pattern of mortality in the flock. These data are measured at the farm and transmitted with the flock at slaughter.
3) Harmonised assessment methods and scoring systems should be developed, and implemented for the identified ABMs. In addition, reliability testing of methods to measure these ABMs is needed.
4) Databases should be used to enable animal welfare benchmarking between and within Member States and risk assessment exercises.
5) Systems for automatic and continuous assessment of ABMs and data recording should be concordant with the standardised manual method. For the assessment of 'FPD', 'wounds', and 'carcass condemnation', automated technologies in the slaughter line should be first fully automated and validated and finally implemented.

4.2.8. Main Recommendations to improve broiler welfare

- Growth rate should be limited to a maximum of 50 g/day to allow the broilers to maintain better health and being active.
- Feed restriction in broiler breeders should be avoided by choosing the appropriate hybrids and feed and management measures.
- A maximum stocking density of 11 kg/m^2 should be applied to allow the broilers to express natural behaviour, to rest properly and to support health.
- Dry and friable litter should be provided from day one and new litter material should be added throughout the rearing period to support comfort and exploratory and foraging behaviour.
- Birds should not be housed in cages but in enclosures that fulfill the minimum requirements as defined in this Scientific Opinion.
- Covered verandas should be provided to broilers and breeders to allow birds to choose between different temperatures, light conditions and substrate quality and promote foraging, exploratory and comfort behaviours.
- Elevated platforms and dark brooders for broilers and perches for broiler breeders should be provided to create functional areas and environmental enrichment to the birds.
- Harmonised assessment methods and scoring systems should be implemented for assessing mortality on farm, wounds, carcass condemnation, and FPD in broilers at slaughter to monitor on-farm welfare of broilers in Europe.
- All forms of mutilation should be avoided in broiler breeders. Preventive measures should be in place to prevent the need of mutilations.

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Glossary

Genetic line	A group (population) of individuals that share a similar genetic background (set of genes) which are distinguished from another group (population) of individuals with a different genetic background.
Genotype	The genotype of an organism is its complete set of genetic material. In that sense, only members of a clone share the same genotype. Alternatively, the word genotype can also refer to a particular gene or set of genes carried by an individual, e.g. in case of mutations. In this sense, different individuals might share the same genotype. The term genotype is also used as the opposite of phenotype (physical appearance) which consists of the genotype plus any influences from the environment and their interactions (modified from Personal Genetics Education Project, online).
Heritage line	These are (pure) lines not used commercially at the moment but are kept for preserving genetic variation. They may have played an important role in the past (therefore the term heritage). They are also called *historical* lines. The population size of these lines is typically smaller than the population size of commercially used genetic lines.
Hybrid	Basically, a hybrid is the offspring resulting from the mating of two organisms of different breeds, varieties, species (Wikipedia, online), or genetic lines. In poultry breeding, genetic lines (i.e. pure lines, definition see above) are selected with different selection criteria. These lines are crossed to yield the grandparents, the grandparent lines are crossed to yield the parent lines and the parent lines are finally crossed to yield the commercially used hybrids. Number of generations may differ and male and female lines with different selection goals are distinguished (of course, all lines consist of males and females). All but the animals of the pure lines are hybrids, meaning that they result from the cross of genetically different populations.
Strain	A strain is basically another term of genetic line. A strain is a population of organism sharing common ancestors and common genes due to artificial selection.
Moulting	Moulting in birds (including chickens) is the (usually yearly) process of shedding feathers and the regrowth of new feathers. It is under hormonal control and occurs when progesterone, oestrogen, and luteinising hormone are low and thyroid hormone and corticosterone are high. Natural moulting is induced by seasonal changes, e.g. in daylength or breeding. In laying hens or broiler breeder hens in production under artificial light regulation it is induced by darkness and feed is withheld to a large extent for about 2–3 weeks. The withdrawal of water is prohibited in some countries but might be in use in others. Moulting leads to a rejuvenation of the reproductive tissue. With age, eggs become continuously larger than at the beginning of lay but after moulting egg size is smaller again compared with before moulting (Oguike et al., 2005).
Pure line	A genetic line (see above) that consists of individuals that interbreed within the line and are not derived from crossing different lines.
Second-grade chicks	After being removed from the hatcher in the hatchery, the quality of the chicks is judged on a binomial scale; first-grade chicks that are saleable and second-grade chicks that are considered non-saleable and therefore culled. Chicks that are classified as second-grade typically fall into the following categories: 1) they are unable to stand straight up, 2) they show visible signs of suboptimal incubation conditions, e.g. red hocks or unhealed navels, or 3) they show deformities (van de Ven et al., 2012).

Abbreviations

ABM	animal based measures
AGRP	agouti-related protein
AHAW	Animal Health and Animal Welfare
AI	artificial insemination
BBFS	Broiler breeders kept in floor systems;
CV	Coefficient of variation
CC	Broiler breeders kept in furnished collective cages
DG Agri	Directorate General Agriculture and Rural Development
EC	European Commission
ECI	End Cage Age Initiative
EFSA	European Food Safety Authority
EKE	Expert knowledge elicitation
EU	European Union
EURCAW Poultry-SFA	European Reference Centre for Animal Welfare for Poultry and other small farmed animals
FPD	Footpad dermatitis
FSCV	Chickens for meat production kept in indoor floor systems with winter garden (covered veranda);
FSFR	Chickens for meat production kept in floor systems with free range;
FSI	Chickens for meat production kept in floor systems (indoor);
HH	Day-old chicks hatched in hatchery;
IC	Broiler breeders kept in individual cages;
MH	Chickens for meat production kept in mobile houses;
MT	Broiler breeders kept in open multi-tier systems.
NEFA	plasma non-esterified fatty acids
NPY	Neuropeptide
NCPs	National Contact Points
PLF	Precision Livestock Farming
PMC	Pro-opiomelanocortin
ToR	terms of Reference
RFID	Radio Frequency identification
SAD	Skip a day
SCAHAW	Scientific Committee in Animal Health and Animal Welfare
WC	Welfare Consequence
WOA	Weeks of age

Appendix A – Questionnaire to EFFAB

Questions from the Working Group and answers from EFFAB on Broiler Breeders (including (great)grandparents and pure lines) kept in individual/collective cages:

1) *Are cages used in Europe? If so, with which frequency?*

- *individual cages?*
- *collective (or colony or group) cages?*

Yes, most of the primary breeders for meat production (dual purpose breeds too)use cages on a continuous basis.
Individual and collective cages are used

2) *What are the exact sizes (length by width by height) for*

- *Individual cages?Individual cages?*
- *collective cages in use?*

There is a different between breeders. Individual cages for males and females can be different. For collective cages, size will depend on the number of birds housed (males and females), the number of birds per cage (collective cages) and the moment they start to be used.

- Individual cages for females: L*W*H (34 to 52 cm * 24 to 49 cm * 38 to 59cm)
- Individual cages for males: L*W*H (34 to 52 cm * 24 to 49 cm * 47 to 65 cm)
- Collective cages: depending of the number of birds housed per cage, size

of collective cages is very variable, L*W*H: 64*120*46 cm and 60*45*40 cm.

3) *For collective cages, what are the usual group sizes? Are there always male and females or are collective cages used for rearing birds in single sex groups?*

Depending on the breeder and type of cages and age of the barn. Older barns have smaller cages compared to new ones.
Collective cages have a variety of group sizes depending of the size of the cage and the way they reproduce. For reproductive performance control, cages can have 1 male + 10 females and up to 40 females with 4 males/have few females that are inseminated (3 to 8)/65 females + 8 males/5 males + 20 females
Rearing is very often performed on floor.

4) *Are cages only used for some strains and/or certain sexes? Please specify if this differs for individual and collective cages*

Cages are often used for pure lines females and pure lines males. Different lines also vary in size, the number of birds in cages will vary depending on the weight/size of the birds. Males can be housed individually. Rearing stage often on floor but not always.
Slower growing lines are in cages to be inseminated (a dwarf male with a normal size hen needs insemination).

5) *When birds are temporarily housed in cages, for how long and during which stage will this be (rearing, production)?*

During the control of laying performance: most often from 18–20 to 64 weeks
(hens have to be controlled on laying performance for 45 weeks).
First stage from 1 week to 17 or 20 (before transfer to the laying control period).

6) *Are cages provided with perches and scratching areas, or are they barren? Please specify if this differs for individual and collective cages*

Perches are available for males in individual cages. In the reproduction stage, for females no specific enrichment is provided.
For the rest, there are barren.

7) *Are cages provided with nests? Please specify if this differs for individual and collective cages*.

For the collective cages, nests are sometimes provided when natural mating. Not always and not at all by some of the breeders.

8) *How often is artificial insemination (AI) used for birds kept in cages? Is it only used for birds in individual cages or also collective ones?*

More often twice a week. Sometimes, every 5 days. Could be on both types of cages.

Insemination is needed for pedigree birds from a designated sire, in order to optimize genetic progress and inbreeding for the renewal of a generation.

9) *Is lighting (daylength, lux etc) similar for birds in cages as for birds housed in non-cage systems and what are the values?*

Lighting is similar. It can go from 15 to 70 lux. It's important to provide similar light conditions to all birds in the barn. Sometimes, roosters have different light time.

10) *Do you have specific information on floor housing for (great) Grand Parents and pure lines, like exact sizes of pens (length by width), number of birds (separately per sex or mixed sexes), litter, perches, nests? Is there a standard size for pens?*

Breeders can house GGP and pure lines flocks on floor and will be variable sized pen, the density depends on the gender, age and line (size of the birds).

Litter, perches, slats can be available, e.g. in adult barn, birds can be on slats.

Nest can also be provided.

Some figures: average of 5 birds/m^2.

11) *Are birds that have been kept in cages (e.g. grandparents and further back in the pyramid) transported from outside into Europe? If so, with which frequency?*

No.

12) *Are brooding eggs shipped to Europe from non- European countries? Are (some) pure lines or (great) grandparents being kept in cages in non-European countries and their eggs shipped to Europe where the offspring is then kept in non-cage systems? If so, which is the frequency of this practices? What proportion of the production this would be?*

Some of the hatching eggs can come from pure lines kept in cages. For the only breeder responding this, this is done approximately every 3 years. Rest of the breeders responded no.

Appendix B – Expert Knowledge Elicitation Report

'Percentage of time walking and footpad dermatitis in relation to stocking density'

This is a summary of the two Expert Knowledge Elicitation exercises.

Part 1 – Expert Knowledge Elicitation exercise description

Purpose of the elicitation

The expert knowledge elicitations exercise aimed at estimating the effect of increasing amounts of space allowance (measured in 'kg/m^2 available to the chicken broilers') on the welfare of broilers thanks to two ABMs: 'the proportion of time during the light period that an average bird is walking' and 'the proportion of footpad dermatitis'.

Choice of the ABMs

The working group chose 'footpad dermatitis (FPD)' as an ABM because it is linked with litter quality (Kaukonen et al., 2017a) which is presumably directly linked with the space allowance and it is frequently measured and available in many studies.

To choose a second ABM, the experts excluded ABMs related to physical walking capacities (lameness, etc.) and selected ABMs which show a positive behaviour of the birds.

Therefore, '% time walking' was chosen as a complementary ABM to FPD to measure the effect of the space allowance, walking being one of the most affected behaviours by space allowance.

Evidence and uncertainty

For each ABM, the Working Group gathered evidence and sources of uncertainty from peer-reviewed literature. Summaries of the evidence and the sources of uncertainty are reported for the two parameters: in Part 2 for time walking and Part 3 for footpad dermatitis.

Definition of the populations

The value of the two ABMs were elicited for three different populations: a 'highly exposed' population, a 'non-exposed' population and an intermediate population.

1) For the purposes of the EKE, the 'highly exposed' population was defined as a hypothetical group of chicken broilers housed in a barn with stocking density of about 35 kg/m^2 which is around what it is currently allowed in the European legislation (Council Directive 2007/43/EC[5]).
2) For the purposes of the EKE, the 'non-exposed' population was defined as a hypothetical group of chicken broilers housed in a barn with stocking density of 1 bird/m^2 (3 kg/m^2 or lower). The non-exposed population of broiler chickens acted as a reference for the value of the ABM in broilers with no restriction of space.
3) Finally, the intermediately exposed population was defined as a hypothetical group of chicken broilers housed in a barn with a stocking density of 20 kg/m^2 which is around the maximum stocking density allowed in organic production[2].

In these three hypothetical populations, the broiler chickens were considered of a 'fast growing' breed aged 5 days before slaughter and housed in a barn with concrete flooring with wood shavings, good ventilation, an environmental temperature of around 20°C and 17 h of light and where good management practices are applied (no leaking water, normal daily care).

EKE attendees, roles and expertise

The elicitation group included an Elicitor and analyst – from the EFSA Assessment and Methodology Unit – experienced in the elicitation of expert knowledge using the Sheffield method – and a recorder – from the EFSA scientific secretariat staff. The experts of the elicitation group were the experts of the Working Group Farm 2 Fork Welfare subgroup 'Welfare of broilers' (EFSA-Q-2020-00479) with two additional experts in the behaviour of broiler chickens. The participants explained their background and relation to the elicitation topic. They were invited to indicate possible conflicts of interests. Participants were made aware that judgements made in the elicitation, and the reasoning used, were going to be recorded, but that they were not going to be attributed to the experts by name (applying the 'Chatham House rule').

Training

At the start of the workshop, the Elicitor gave a short training about the EKE process. Afterwards, the Elicitation experts carried out a practice elicitation in which each expert gave a proportion for an example question. The Elicitor explained that for the questions that followed, the group would also be asked to arrive at a consensus proportion or range of proportions expressing their collective judgement.

The elicitation protocol

For each ABM, the EKE was carried out according to the following steps:

a) The question was reviewed and any queries were clarified.
b) The evidence was reviewed: the relevant section of the Evidence dossier was examined. Any points of clarification or differences were discussed; participants were asked to summarise any additional evidence they considered relevant.
c) Question 1: Elicitation of the ABM for the highly exposed population: the parameter elicited was the value of the ABM in a highly exposed population (35 kg/m^2). The expert knowledge elicitation was conducted in three steps:

   - 1st step: The group of experts were asked to write down their initial judgements on the parameter individually, expressed as lower and upper limit, followed by the best estimate for the median estimate, and finally as interquartile range (1st and 3rd quartile) to express their uncertainty about their estimate. The experts were invited to reflect on the evidence provided and the important factors that can influence the value of the parameter.
   - 2nd step: Then, the initial individual judgements were collected and immediately visualised in a table. The Elicitor facilitated a discussion on the reasons of the judgements made and asked the experts to consider individually whether to retain their initial judgement or amend it.
   - 3rd step: Finally, the Elicitor facilitated a discussion working towards a consensus judgement expressing the collective view of the group. The Elicitor checked for agreement on the result of this discussion before moving on to the next question.

d) Question 2: Agreement on the coefficient of variation (CV) of the ABM for the highly exposed population (35 kg/m^2). The coefficient of variation represents how much the ABM varies in a population and the higher the coefficient of variation the more factors contribute to this variation and not only the investigated exposure variable (i.e. the stocking density). For both ABMs, the CV was not elicited and set according to the available literature.
e) Question 3: Elicitation of the ABM for the intermediately exposed population: the parameter elicited was the relative variation of the value of the ABM between the highly exposed population and an intermediately exposed population (stocking density=20 kg/m^2). The elicitation for this population was conducted in three steps similarly to the elicitation for highly exposed population (see c).
f) Question 4: Elicitation of the ABM for the non-exposed population: the parameter elicited was the relative variation of the value of the ABM between the highly exposed population and a non-exposed population (stocking density 3 kg/m^2). For the ABM% of walking, the elicitation for the non-exposed population was conducted in three steps similarly to the elicitation for highly exposed population (see c). For the ABM footpad dermatitis score, the score was assumed to be 0 in a non-exposed population.
g) Question 5: Elicitation of the maximum stocking density without change: the parameter elicited was the maximum stocking density resulting in no change in the value of the ABM compared to the value observed in the non-exposed population. The elicitation of the maximum stocking density without change in comparison to the non-exposed population was conducted in three steps similarly to the elicitation for highly exposed population (see c).

Part 2 – EKE 1 on percentage of time walking

Purpose

The expert knowledge elicitation 1 (EKE 1) exercise aimed at estimating the effect of increasing amounts of stocking density (measured in 'kg/m^2 and is a proxy for the space available to the broiler chickens') on 'the proportion of time during the light period that an average bird is walking'.

Evidence

The evidence extracted by the experts is presented in Table B.1 below. In total, nine papers were identified.

The extracted data were depicted in Figure B.1 showing the relationship between stocking density and % time walking.

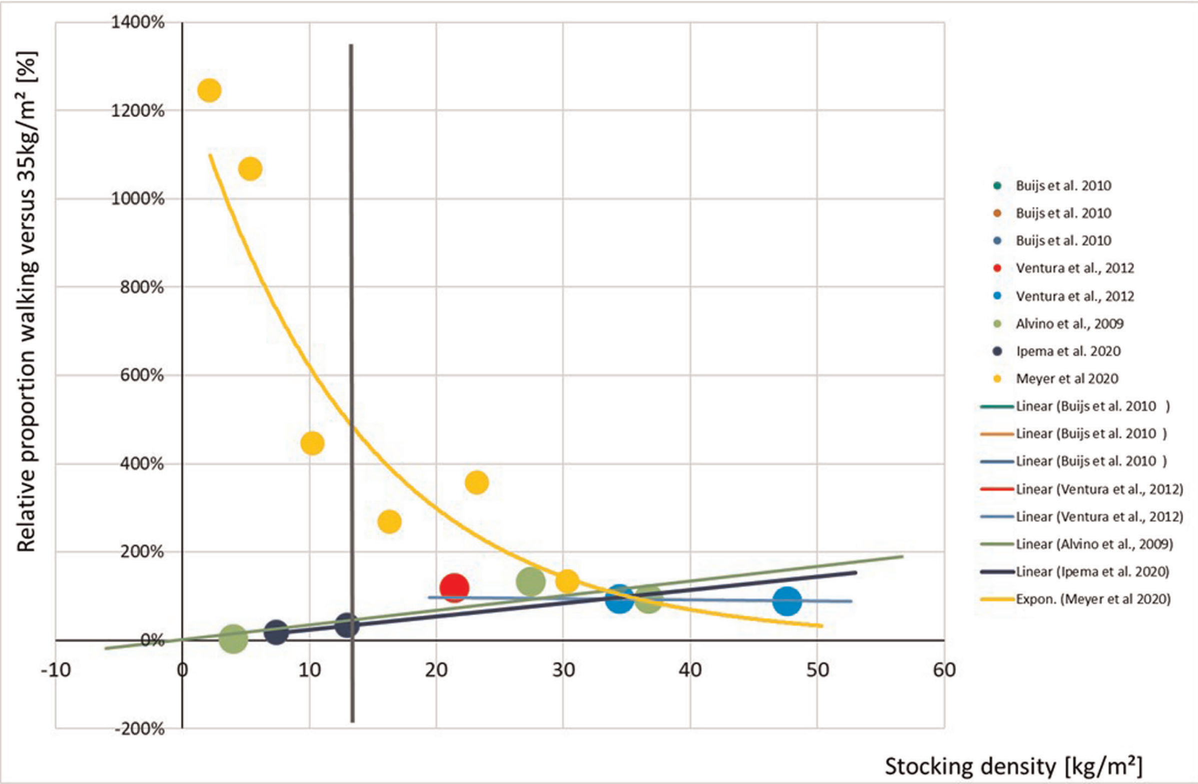

Figure B.1: Relative proportion of walking in comparison to a stocking density of 35 kg/m^2

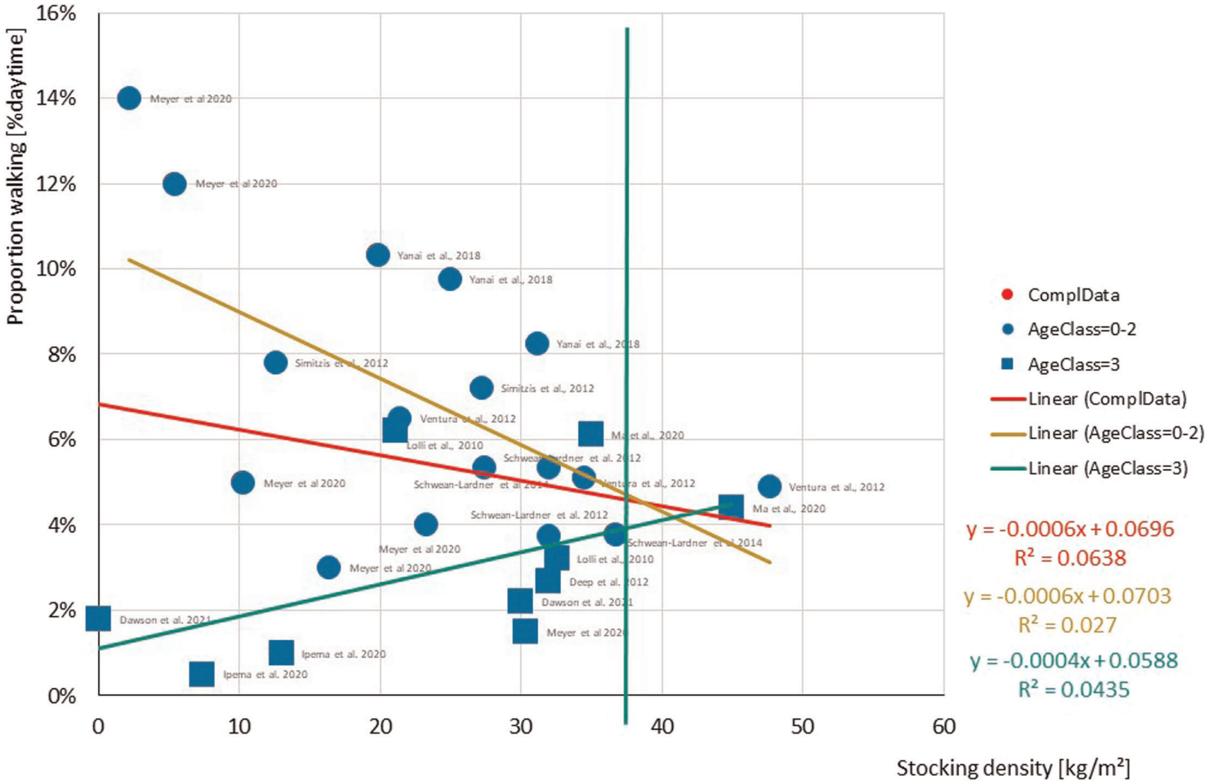

Figure B.2: Scatterplot of % time walking and stocking density of broilers of 3 age classes (Age class: 3= >=42 d; 2= 35–< 42 d; 1= 26–< 35 d 0= < 26 d) and the linear relationship for age class 0–2 and age class 3

Table B.1: Summary of data reported in the scientific literature on % time walking showed by broilers in different stocking densities (kg/m^2) stratified in different age groups (Age class: 3= >=42 d; 2= 35–< 42 d; 1= 26–< 35 d 0= < 26 d)

Reference	Stocking density (kg/m^2)	Prop. Walking (% of light time)	Age class	Remarks
Yanai et al. (2018)	19.8	10.3	0	Scan sampling, from d 14 to slaughter (4 weeks), 3 days per week 2 h per day, each 5 min one scan.
	25.0	9.8	0	
	31.1	8.2	0	
Ventura et al. (2012)	21.4	6.5	3	Instantaneous scan sampling of focal birds.
	34.4	5.1	3	
	47.6	4.9	3	
Schwean-Lardner et al. (2014)	27.4	5.3	1	Scan sampling at 10 min intervals at 27–28 and 42–43 days of age during the full 24 h period. Different photoperiods: data extracted from the 14 h light period treatment.
	36.7	3.8	3	
Meyer et al. (2020)	2.2	14.0	0	Focal bird sampling; 4 × 4 min per 24 h (every 6 h).
	5.4	12.0	0	
	10.2	5.0	0	
	16.4	3.0	1	
	23.2	4.0	2	
	30.3	1.5	3	
Lolli et al. (2010)	21.1	6.2	3	Scan sampling and focal sampling from one-hour video recordings at 42 days of age. Data collected under high ambient temperatures (33°C).
	32.5	3.2	0	

Reference	Stocking density (kg/m^2)	Prop. Walking (% of light time)	Age class	Remarks
Ma et al. (2020)	35	6.1	3	4 Marked broilers were observed for 2 h per day on 4 days before slaughter.
	45	4.4	3	
Simitzis et al. (2012)	12.6	7.8	0	Number of broilers moving between adjacent video frames, with 1 sec difference, in two pens per treatment.
	27.2	7.2	0	
Alvino et al. (2009)	4	3.0	1	Scan sampling from video recordings of 48 h at 3, 4 and 5 weeks of age (% walking is the average of all ages). Study on different light intensities, but no difference in % time walking.
Ipema et al. (2020)	7.4	1.0	1	Instantaneous scan sampling (12-min intervals) on days 7 14, 21, 28 and 36, with seven one-hour periods starting at 08:00, 09:15, 10:45, 12:00, 13:45, 15:00 and 16:30, resulting in 35 scans/ broiler/day.
	13.0	2.0	2	

Source of uncertainty

The experts gathered the main factors (other than space allowance) that can influence the percentage of time walking:

1) Addition of environmental enrichment: environmental enrichment is suggested to stimulate the activity of broiler chickens as birds walk to the enrichments (Kaukonen et al., 2017b) but the proportion of time walking could decrease as birds may rest on the structures without being disturbed.
2) Age of the birds: activity level in broiler chickens decreases with age (van der Sluis et al., 2019), which is suggested to be caused by the increasing weight of the birds.
3) Light intensity and schedule: intermittent lighting schedules and higher light intensities increase activity and thus the time spent on walking (Blatchford et al., 2012; Rault et al., 2017; Sun et al., 2017).
4) Natural light: daylight is suggested to increase the locomotor activity (Bailie et al., 2013; de Jong and Gunnink, 2019).
5) Climate in the house: with high environmental temperatures, broiler chickens generally decrease their locomotor activity to avoid extra metabolic heat production (Branco et al., 2021; Akter et al., 2022).

1. Question 1: Elicitation of the percentage of time walking in a highly exposed population (stocking density = 35 kg/m^2)

See Table B.2 for an overview of the results for the first question concerning a highly exposed population.

Table B.2: Overview of the results of the Expert Knowledge Elicitation (1st question)

Parameter	Median ABM % time walking with high stocking density (stocking density = 35 kg/m^2)														
Stratification	Fast-growing broiler chickens for meat production														
Question	What is the average proportion of walking during light time (approx. 17 h), that is shown in a flock of broilers with high stocking density (ABM with stocking density of 35 kg/m^2) for a median broiler (median of the distribution) up to five days before slaughter? [%]														
Results	P1%	P2.5%	**P5%**	P10%	P16.7%	P25%	P33.3%	**P50%**	P66.7%	P75%	P83.3%	P90%	**P95%**	P97.5%	P99%
Elicited values	1.00					3.00		4.00		7.00					11.0
EKE results	0.99	1.11	1.29	1.64	2.09	2.66	3.24	4.48	5.90	6.74	7.73	8.72	9.72	10.4	11.1
Fitted distribution	BetaGeneral (1.1242, 2.0837, 0.9, 12.2)														

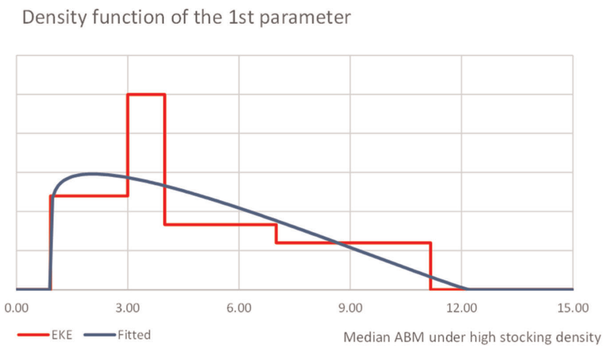

Figure (a): Comparison of elicited and fitted values/density function to describe the remaining uncertainties of the parameter

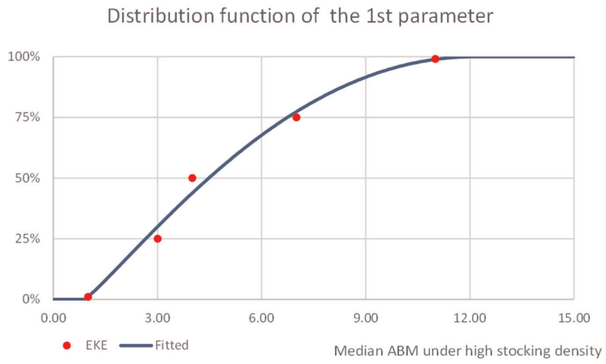

Figure (b): Cumulative distribution function (CDF) of the likelihood of the parameter

2. Question 2: Agreement on the coefficient of variation of the % time walking in a highly exposed population (35 kg/m^2)

See Table B.3 for an overview of the results for the 2nd question.

Table B.3: Overview of the results of the Expert Knowledge Elicitation (2nd question)

Parameter	High ABM % time walking under very high stocking density
Stratification	Fast-growing broiler chickens for meat production
Question	What is the variation of the average % time walking, that is shown in a flock of broilers (up to 5 days before slaughter) with very high stocking density of 35 kg/m^2 expressed as coefficient of variation (CV) between the flocks? [−]
Results	0.5 (Median value without uncertainty)
Fitted distribution	Constant
Main uncertainties	
• The uncertainty of the full distribution is covered by the uncertainty on the median (Question 1)	

The CV for % time walking was not elicited but the value was agreed after group discussion based on the available literature included above. The CV was set to 0.5 as CV between the six studies used for question 1. It is assumed, that each study is using only few birds of the flock and that inter-study variation is a proxi for between bird variation.

3. Question 3: Elicitation of the percentage of walking in an intermediately exposed population (20 kg/m^2)

See Table B.4 below for an overview of the results for the third question for an intermediately exposed population.

Table B.4: Overview of the results of the Expert Knowledge Elicitation (2nd question)

Parameter	Median ABM % time walking under intermediately exposed population stocking density (20 kg/m^2)														
Stratification	Fastgrowing broiler chickens for meat production														
Question	What is the relative increase of the proportion of walking during light time (approx. 17 h), that is shown in a flock of broilers with intermediate stocking density (stocking density of 20 kg/m^2) in relation to high stocking density for a median broiler (median of the distribution) up to five days before slaughter? [%]														
Results	P1%	P2.5%	**P5%**	P10%	P16.7%	P25%	P33.3%	**P50%**	P66.7%	P75%	P83.3%	P90%	**P95%**	P97.5%	P99%
Elicited values	1.20					1.25		1.43		1.55					1.75
EKE results	1.20	1.20	1.20	1.21	1.23	1.26	1.30	1.40	1.51	1.58	1.64	1.69	1.73	1.74	1.75
Fitted distribution	BetaGeneral (0.56222, 0.82259, 1.2, 1.755)//alternative (non-U-shape: RiskBetaGeneral (0.63112, 1.0435, 1.2, 1.8))														

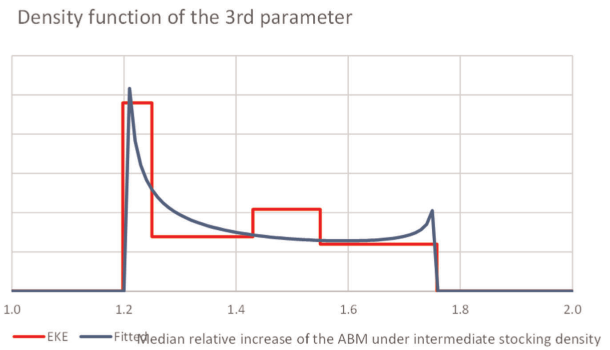

Figure (a): Comparison of elicited and fitted values/density function to describe the remaining uncertainties of the parameter

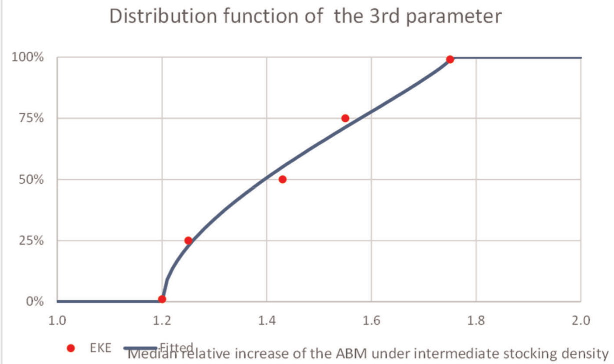

Figure (b): Cumulative distribution function (CDF) of the likelihood of the parameter

4. Question 4: Elicitation of the percentage of walking in a low exposed population (3 kg/m^2)

See Table B.5 below for an overview of the results for the fourth question.

Table B.5: Overview of the results of the Expert Knowledge Elicitation (3rd EKE question)

Parameter	Median % time walking with low stocking density (3 kg/m^2)														
Stratification	Fast-growing broiler chickens for meat production														
Question	What is the relative increase of the proportion of walking during light time (approx. 17 h), that is shown in a flock of broilers with low stocking density (ABM with stocking density of 3 kg/m^2) in relation to high stocking density for a median broiler (median of the distribution) up to five days before slaughter? [%]														
Results	P1%	P2.5%	**P5%**	P10%	P16.7%	P25%	P33.3%	**P50%**	P66.7%	P75%	P83.3%	P90%	**P95%**	P97.5%	P99%
Elicited values	1.4					1.6		2.0		2.3					2.5
EKE results	1.40	1.41	1.42	1.46	1.52	1.61	1.71	1.93	2.15	2.26	2.36	2.43	2.48	2.50	2.51
Fitted distribution	BetaGeneral (0.71825, 0.76428, 1.4, 2.51)														

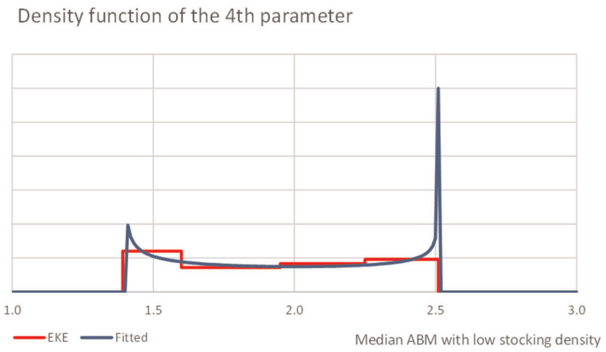

Figure (a): Comparison of elicited and fitted values/density function to describe the remaining uncertainties of the parameter

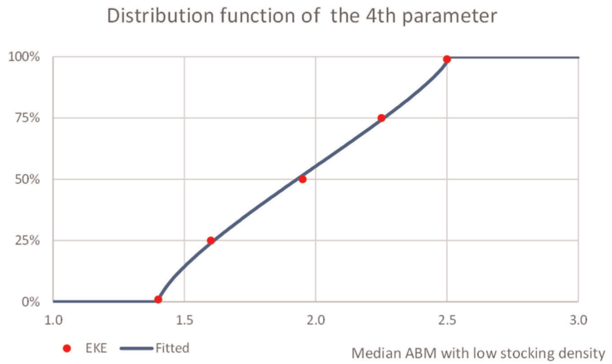

Figure (b): Cumulative distribution function (CDF) of the likelihood of the parameter

5. Question 5: Elicitation of the maximum stocking density without a decrease into percentage of time walking

See Table B.6 below for an overview of the results for the fourth question.

Table B.6: Overview of the results of the Expert Knowledge Elicitation (4th EKE question)

Parameter	Maximal stocking density without effect														
Stratification	Fast-growing broiler chickens for meat production														
Question	What is the maximuml stocking density with no effect on the % of time walking compared to the unexposed broilers (stocking density of 3 kg/m^2)? [kg/m^2]														
Results	P1%	P2.5%	**P5%**	P10%	P16.7%	P25%	P33.3%	**P50%**	P66.7%	P75%	P83.3%	P90%	**P95%**	P97.5%	P99%
Elicited values	8					10		12		15					17
EKE results	8.03	8.10	8.25	8.59	9.11	9.83	10.6	12.3	14.0	14.8	15.7	16.3	16.7	16.9	17.0
Fitted distribution	BetaGeneral (0.79469, 0.86317, 8,17.1)														

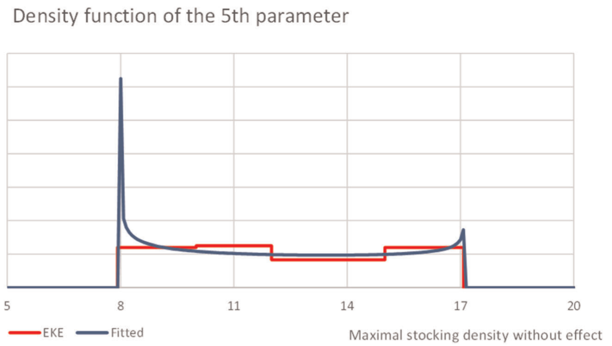

Figure (a): Comparison of elicited and fitted values/density function to describe the remaining uncertainties of the parameter

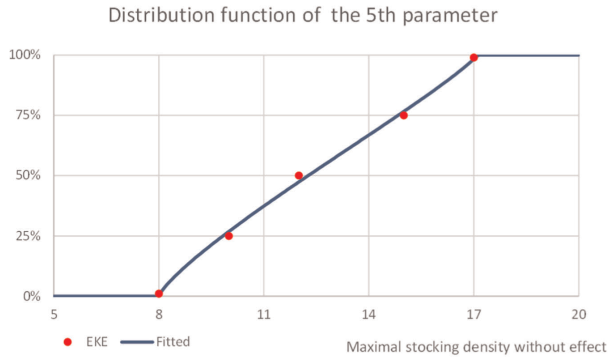

Figure (b): Cumulative distribution function (CDF) of the likelihood of the parameter

6. Results of the risk assessment (for % of time walking)

See Figure 15 in Section 3.5.1.1 of the Scientific Opinion Welfare of broilers on farm.

Part 3 – EKE 2 on percentage of footpad dermatitis

Purpose

The expert knowledge elicitation 2 (EKE 2) exercise aimed at estimating the effect of increasing amounts of stocking density (measured in 'kg/m^2 and a proxy for the available space to the broiler chickens') on the Footpad dermatitis score.

Evidence

In total 18 studies were identified reporting FPD scores and stocking densities. This data is included in Table B.7.

Figure B.3 shows the regression of the average FPD score in response to stocking density by age subgroups (28 -to 35 d; 35 to 42d; > 42 d). The FPD scores increase linearly with increasing stocking density. The age group of 28 to 35 d shows the steepest slope within a range of stocking density from about 20 kg/m^2 to 38 kg/m^2 and the age group > 42 days showed the lowest slope in a range from 20 kg/m^2 to nearly 70 kg/m^2, the age group from 35 to 42 d takes an intermediate position. This shows that broilers of age group < 35 d are more susceptible to develop FPD to high stocking density than birds from the higher age groups. Indeed, the highest observed FPD scores appear in the groups of up to 42 d of age. There exists a high variation of FPD scores in all groups and scores < 0.5 occur in all age groups. The coefficient of determination of the linear regression fitted ranged from 0.25 to 0.33. Within the stocking density range of about 28 kg/m^2 to 60 kg/m^2, the mean scores vary from 0 to 2.0. This indicates that factors other than stocking density may be involved in the expression of FPD. The most important factor is wet litter (Manning et al., 2007b), which is not only influenced by stocking density but also by ambient temperature, technique of water supply, diets, diseases and ventilation (Manning et al., 2007a).

The EKE study based on these results revealed that stocking density of 10 kg/m^2 would show a 100% reduction of FPD while no reduction would be expected from stocking densities of 36 kg/m^2 onwards.

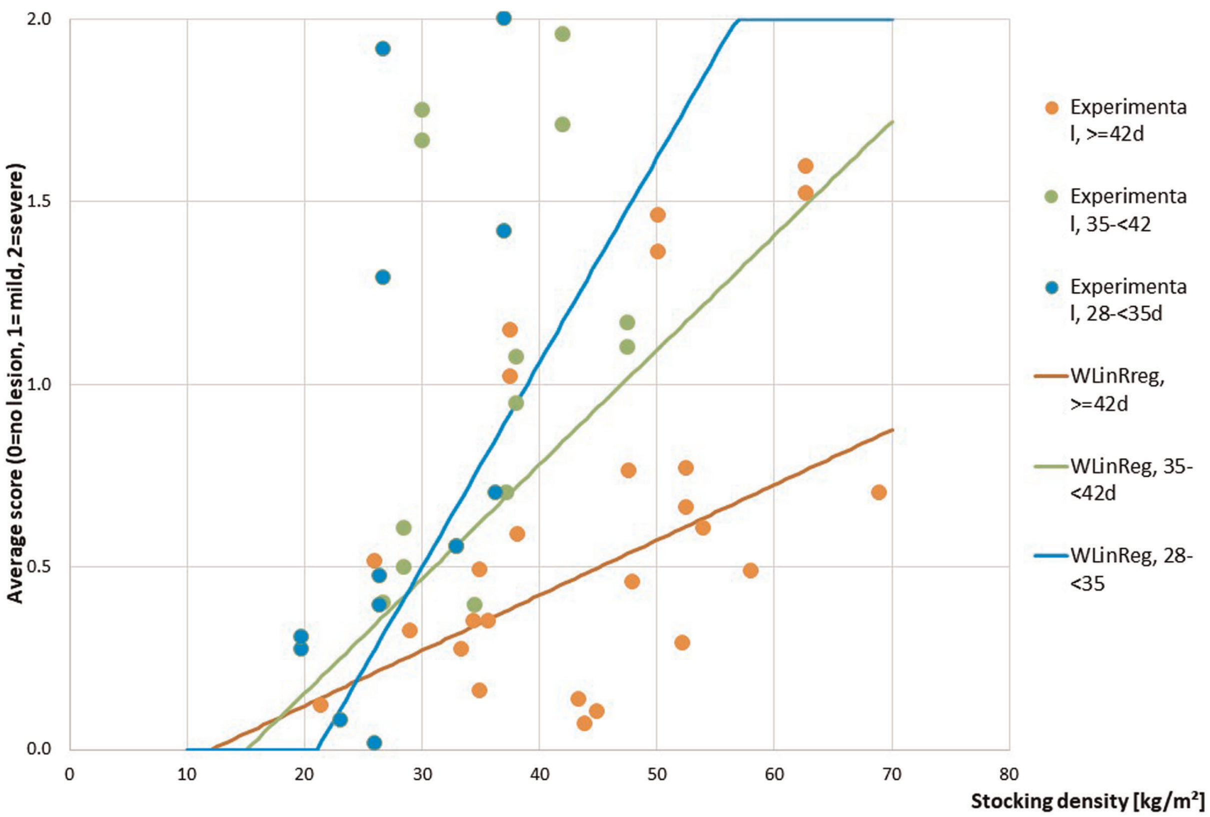

Figure B.3: Plot of the extracted data for the relation of stocking density and average FPD score stratified in three age groups. Linear trends are weighted with the sample size

Table B.7: Summary of data reported in the scientific literature on FPD showed by broilers in different space allowances stratified by age group

Reference	Stocking density [kg/m^2]	Footpad Score	Age class (0 to 3)	Remarks
(Bailie et al., 2018a)	21.08	1.20	1	% lesions > 3mm
	22.84	1.30	1	
	24.60	1.35	1	
	26.36	1.35	1	
	30.00	0.79	2	
	32.00	0.77	2	
	34.00	0.68	2	
	36.00	0.75	2	
(Bergeron et al., 2020)	24.10	0.48	2	
	14.17	0.17	2	
(BenSassi et al., 2019c)	29.83	0.13	1	
	27.38	0.07	1	
	35.41	0.01	1	
	38.05	0.02	1	
	41.56	0.01	1	
	31.94	0.01	1	
	32.07	0.02	1	
	33.98	0.01	1	
	34.14	0.01	1	
	29.75	0.05	1	
	37.36	0.01	1	
	34.44	0.02	1	
	36.36	0.01	1	
	34.65	0.04	1	
	34.91	0.01	1	
	38.25	0.01	1	
	29.16	0.01	1	
	28.43	0.01	1	
	30.87	0.03	1	
	30.45	0.01	1	
	27.03	0.01	1	
	36.84	0.01	1	
	29.16	0.01	1	
	31.40	0.02	1	
	35.46	0.01	1	
	31.51	0.05	1	
	34.29	0.02	1	
	39.25	0.03	1	
	35.40	0.01	1	
	37.15	0.04	1	
(Cengiz et al., 2018)	43.90	0.07	3	
	68.99	0.70	3	
	7.38	0.00	0	
	11.59	0.05	0	
	23.11	0.08	1	
	36.32	0.70	1	

Reference	Stocking density [kg/m^2]	Footpad Score	Age class (0 to 3)	Remarks
(Deep et al., 2012)	31.14	2.7	0	Camera placed above pen for one day and every, 10 min (instantaneous scan) number of birds performing each activity recorded.
(Farhadi and Hosseini, 2016)	29.06	0.32	3	Thomas et al., 2004: score 1 no lesions, score 2 mild lesions and score 3 large or deep lesions
	33.40	0.27	3	
	35.67	0.35	3	
	38.16	0.59	3	
(Lolli et al., 2010)	21.11	6.20	2	High temperature
(Ipema et al., 2020)	7.43	0.5	1	Observed at 12-min intervals by instantaneous scan sampling on one day at the end of week 1–5 (day 7, 14, 21, 28 and 36). This involved seven one-hour periods starting at 08:00, 09:15, 10:45, 12:00, 13:45, 15:00 and 16:30, resulting in 35 scans/broiler/day.
	13.01	1.0	1	
(Rashidi et al., 2019)	35.02	0.16	3	
	52.52	0.77	3	
(Petek et al., 2014)	45.00	0.10	3	Footpad lesion length: Mild < 8 = 7.5 mm, severe > 7.5 mm, None, no lesion present.
	52.21	0.29	3	
	58.05	0.49	3	
	43.37	0.14	3	
	48.03	0.46	3	
	53.98	0.60	3	
(Ipema et al., 2020)	7.43	0.5	1	Observed at 12-min intervals by instantaneous scan sampling on one day at the end of week 1–5 (day 7, 14, 21, 28 and 36). This involved seven one-hour periods starting at 08:00, 09:15, 10:45, 12:00, 13:45, 15:00 and 16:30, resulting in 35 scans/broiler/day.
	13.01	1.0	1	
(Vargas-Galicia et al., 2017)	30.00	1.67	2	Bilgili et al., 2006; 0 no lesion, 1 mild lesion < 0.75 cm, 2 larger lesion < 1.5 cm, 3 severe lesion larger than 1.5 cm
	42.00	1.96	2	
	30.00	1.75	2	
	42.00	1.71	2	
	17.76	0.79	0	
	24.59	1.46	0	
	17.76	1.42	0	
	24.59	1.00	0	
	26.75	1.29	1	
	37.04	2.00	1	
	26.75	1.92	1	
	37.04	1.42	1	
(Ventura et al., 2010)	21.42	0.12	3	0 equated to no evidence of lesions and 4 to severe lesions (WQ) 0.03 0 = no lesions; 1 = mild lesion affecting a very small area, of skin; 2 = severe lesion; and 3 = grossly affected, region with lesion covering most of the footpad area. Intermediate scores using one-half points (e.g. 1.5, 2.5) were used to characterize lesions that were intermediate between the points on the original scale
	34.45	0.35	3	
	47.65	0.76	3	

Reference	Stocking density [kg/m^2]	Footpad Score	Age class (0 to 3)	Remarks
(Vissers et al., 2019)	36.05	0.13	2	
	36.05	0.22	2	
	38.69	0.50	2	
	38.67	0.48	2	
	39.41	0.13	1	
	37.87	0.22	2	
	29.83	0.13	1	
	34.67	0.45	2	
	33.97	1.16	1	
	35.09	0.99	2	
	32.27	1.17	2	
	32.45	1.27	2	
	31.06	0.13	3	
	36.89	0.28	3	
	37.73	0.53	2	
	37.45	0.51	1	
	29.46	0.47	2	
	33.96	0.49	2	
	31.47	1.37	3	
	37.66	0.70	1	
	39.26	1.16	1	
	41.49	0.80	2	
	38.43	0.75	1	
	40.82	0.04	2	
	36.70	0.15	1	
	41.85	1.67	2	
	34.28	0.58	2	
	35.94	1.37	1	
	36.34	1.75	3	
	28.41	0.35	3	
	31.49	0.77	3	
	38.24	0.22	3	
	41.00	0.42	3	
	41.14	1.64	2	
	43.09	0.80	1	
	37.20	0.36	2	
	37.79	0.25	2	
	35.69	0.18	2	
	36.05	0.81	2	
	39.00	1.09	1	
	39.08	0.98	2	
	37.99	0.22	1	
	37.43	0.76	2	
	25.80	1.88	2	
	26.33	1.01	2	
	39.41	1.31	1	
	44.21	0.56	1	
	38.13	0.03	1	

Reference	Stocking density [kg/m^2]	Footpad Score	Age class (0 to 3)	Remarks
	33.96	0.07	1	
	33.08	0.98	2	
	32.71	0.64	2	
	36.20	0.65	2	
	39.72	1.15	2	
	38.37	0.88	2	
	33.80	1.18	1	
	40.43	1.12	2	
	41.99	1.56	2	
	33.40	1.08	3	
	37.65	0.71	2	
	38.28	1.13	1	
	40.81	0.70	1	
	33.48	1.57	1	
	31.19	0.27	1	
	35.64	0.14	1	
	34.61	0.24	1	
	35.06	1.60	3	
	32.94	0.67	2	
	35.55	0.84	2	
	33.98	1.16	3	
	34.64	0.19	2	
	40.16	0.22	2	
	40.18	0.17	1	
	37.80	0.17	1	
	39.11	0.70	3	
	37.19	0.54	2	
(Zhao et al., 2013)	50.18	1.36	3	Relatively low-speed displacement of bird on the ground in which the propulsive force is derived from the action of the legs.
	62.72	1.52	3	
	37.63	1.15	3	
	50.18	1.46	3	
	62.72	1.59	3	
	28.51	0.50	2	
	38.02	0.95	2	
	47.52	1.10	2	
	28.51	0.61	2	
	38.02	1.07	2	
	47.52	1.17	2	
	19.81	0.27	1	
	26.42	0.39	1	
	33.02	0.55	1	
	19.81	0.31	1	
	26.42	0.47	1	
	33.02	0.55	1	

In total, 18 studies were found reporting on FPD under different stocking densities. We therefore included data of other studies where both the time spent walking and the stocking density were provided. There was a high variation in the FPD scores, likely due to other factors than stocking density. There is a lack of data on the FPD in low stocking densities. Further, it was assumed that an unexposed population (very low stocking density) would show an FPD score of 0.

Sources of uncertainty

The experts gathered the main factors (other than space allowance) that can influence the Footpad dermatitis score:

1) Environmental enrichment: Environmental enrichment (e.g. well-designed elevated resting areas) is expected to increase the time spent active and to reduce the contact time of the feet and hocks with wet litter and thus may reduce the development of footpad dermatitis. However, there is a lack of consensus in the literature on the positive effect of environmental enrichment. The type and design of enrichment and the extent to which it is actually used by the birds may explain the contradicting results.
2) Age: The incidence of FPD usually increases with the bird's age. However, the development of FPD may be initiated in very young birds but this phenomenon has not been fully studied. Some studies show a slight improvement of FPD at the end of the growing period.
3) Climatic conditions
4) Light regime: Short light phases are known to increase locomotor activity including scratching and pecking in the litter. This keeps the litter brittle and prevents caking.
5) Natural light: Natural light is considered to stimulate scratching and litter pecking behaviour and thus reduce the incidence of FPD. However, the effect of natural light is confounded with other management environmental factors in most cases and its influence needs to be studied more extensively.

1. Question 1: Elicitation of the footpad dermatitis score in a high exposed population (35 kg/m^2)

See Table B.8 for an overview of the results for the first question.

Table B.8: Overview of the results of the Expert Knowledge Elicitation (1st EKE question)

Parameter	Median FPD under high stocking density (35 kg/m^2)														
Stratification	Fast-growing broiler chickens for meat production														
Question	What is the average score of footpad dermatitis, that is shown in a flock of broilers (up to 5 days before slaughter) with very high stocking density of 30–40 kg/m^2 (ABM with very high stocking density) for a median flock (median of the distribution)?														
Results	P1%	P2.5%	**P5%**	P10%	P16.7%	P25%	P33.3%	**P50%**	P66.7%	P75%	P83.3%	P90%	**P95%**	P97.5%	P99%
Elicited values	0.15					0.40		0.65		0.85					1.10
EKE results	0.15	0.17	0.20	0.26	0.33	0.41	0.49	0.64	0.78	0.86	0.94	1.00	1.05	1.08	1.10
Fitted distribution	BetaGeneral (1.2062, 1.1629, 0.131, 1.117)														

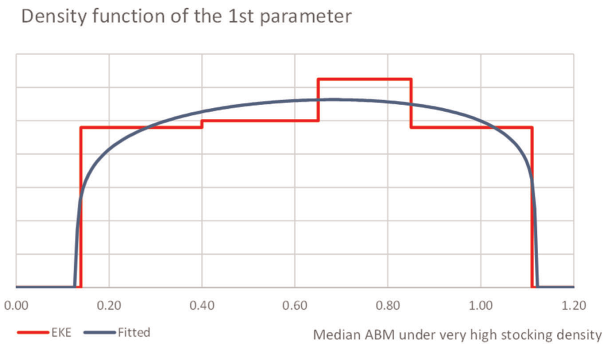

Figure (a): Comparison of elicited and fitted values/density function to describe the remaining uncertainties of the parameter

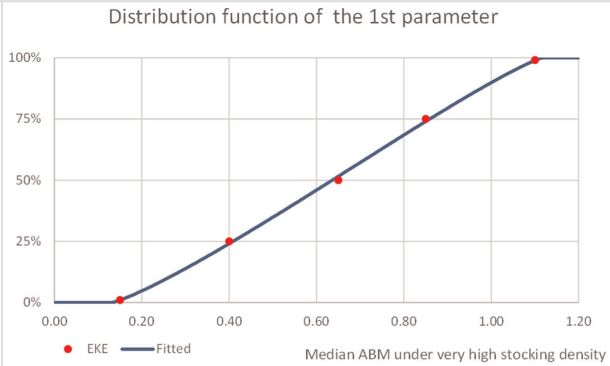

Figure (b): Cumulative distribution function (CDF) of the likelihood of the parameter

2. Question 2: Agreement on the coefficient of variation of the footpad dermatitis score in a highly exposed population (35 kg/m^2)

See Table B.9 for an overview of the results for the 2nd question.

Table B.9: Overview of the results of the Expert Knowledge Elicitation (2nd EKE question)

Parameter	High ABM FPD score under very high stocking density
Stratification	Fast-growing broiler chickens for meat production
Question	What is the variation of the average score of footpad dermatitis, that is shown in a flock of broilers (up to 5 days before slaughter) with very high stocking density of 35 kg/m^2 expressed as coefficient of variation (CV) between the flocks?
Results	0.7 (Median value without uncertainty)
Fitted distribution	Constant
Summary of the evidence used for the evaluation	
• Studies with on-farm measurements were reviewed. Some studies allowed the calculation of a CV: Bailie et al., 2018a; BenSassi et al., 2019c • The study of Vissers et al. was considered as best representing the European situation • The CV of the oldest age group as the population of interest (broiler chickens up to 5 days before slaughter) of Vissers et al. was rounded to: 0.7	
Main uncertainties	
• The uncertainty of the full distribution is covered by the uncertainty on the median (Question 1)	

The CV for FPD was not elicited but the value was agreed after group discussion based on the available literature included above. The CV was set at 0.70.

3. Question 3: Elicitation of the footpad dermatitis score in an intermediately exposed population (stocking density 20 kg/m^2)

See Table B.10 for an overview of the results for the third question.

Table B.10: Overview of the results of the Expert Knowledge Elicitation (3rd EKE question)

Parameter	Median FPD score with intermediate stocking density (20 kg/m^2)														
Stratification	Fast-growing broiler chickens for meat production														
Question	What is the average score of footpad dermatitis, that is shown in a flock of broilers (up to 35 days before slaughter) with low stocking density of 20 kg/m^2 (ABM with low stocking density) for a median flock (median of the distribution)?														
Results	P1%	P2.5%	**P5%**	P10%	P16.7%	P25%	P33.3%	**P50%**	P66.7%	P75%	P83.3%	P90%	**P95%**	P97.5%	P99%
Elicited values	0.05					0.13		0.30		0.43					0.70
EKE results	0.05	0.05	0.06	0.08	0.10	0.14	0.18	0.28	0.39	0.45	0.52	0.59	0.64	0.68	0.70
Fitted distribution	BetaGeneral (0.78375, 1.2808, 0.0485, 0.725)														

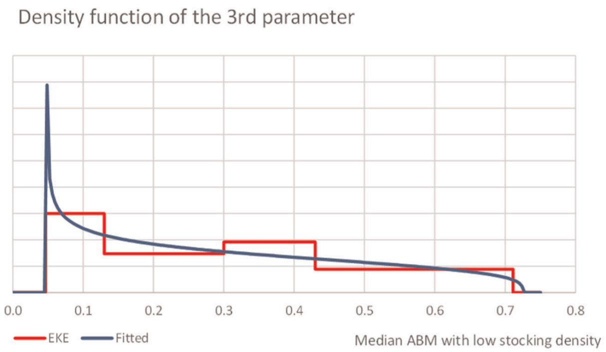

Figure (a): Comparison of elicited and fitted values/density function to describe the remaining uncertainties of the parameter

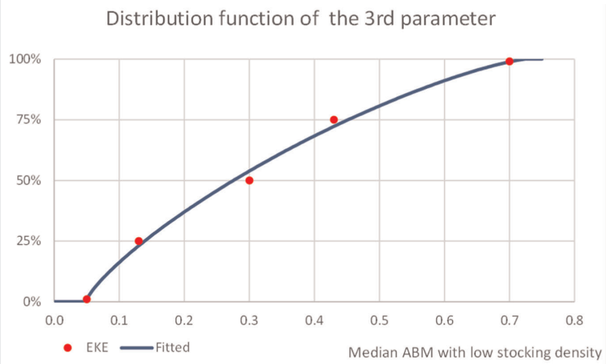

Figure (b): Cumulative distribution function (CDF) of the likelihood of the parameter

4. Question 4: Elicitation of the footpad dermatitis score in a non-exposed population (3 kg/m^2)

The working group assumed that an unexposed population (very low stocking density) would show an FPD score of 0.

5. Question 5: Elicitation of the maximum stocking density without change for the footpad dermatitis score

See Table B.11 for an overview of the results for the 5th EKE question.

Table B.11: Overview of the results of the Expert Knowledge Elicitation (5th EKE question)

Parameter	Maximal stocking density without effect														
Stratification	Fast-growing chickens for meat production														
Question	What is the maximum stocking density with no effect on the average footpad dermatitis score compared to the unexposed broilers (stocking density of 3 kg/m^2)? [kg/m^2]														
Results	P1%	P2.5%	**P5%**	P10%	P16.7%	P25%	P33.3%	**P50%**	P66.7%	P75%	P83.3%	P90%	**P95%**	P97.5%	P99%
Elicited values	5.0					7.0		10.0		14.0					18.0
EKE results	5.0	5.06	5.19	5.53	6.10	6.95	7.91	10.1	12.6	13.9	15.3	16.5	17.3	17.8	18.0
Fitted distribution	BetaGeneral (0.72303, 0.98757, 4.98, 18.2)														

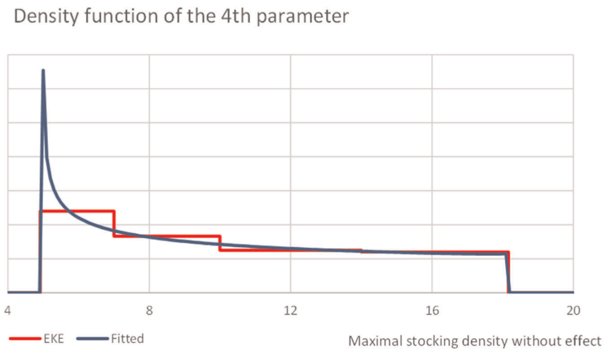

Figure (a): Comparison of elicited and fitted values/density function to describe the remaining uncertainties of the parameter

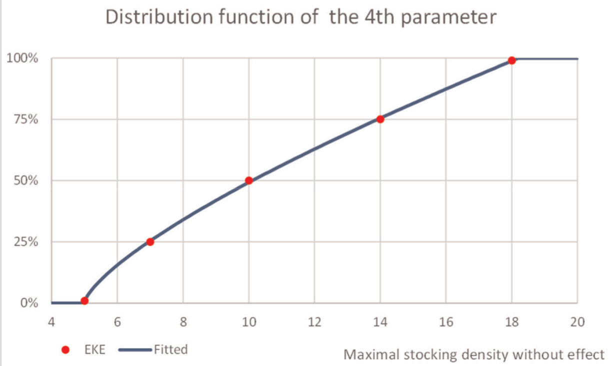

Figure (b): Cumulative distribution function (CDF) of the likelihood of the parameter

6. Results of the risk assessment (for FPD score)

Three values (shown in pink with grey certainty ranges) were obtained by EKE. A stepwise linear relationship between increasing space allowances (kg/m^2) and average FPD score is assumed (pink line) to interpolate the EKE results. The red, vertical distribution on the right-hand side of the plot represents the variability in the average FPD score expected in a population of broilers placed in a barn with highly restricted space (e.g. minimal allowed space).

See Figure 16 in Section 3.5.1.1 of the Scientific Opinion Welfare of broilers on farm.

Appendix C – Evidence extracted for the behavioural model

Data extraction (behaviour during scan sampling)

Table C.1: Extracted data for the behaviours selected in the behavioural space model. Given are the behaviours and their label of valence, the references and the proportion of birds performing each behaviour as well as the total number of references [k=17], the data points extracted [N=81] and the average number of data points per behaviour [n=9]

Behaviour	**Label**	**Aldridge et al., 2021**	**Alvino et al., 2009**	**Bailie and O'Connell, 2014**	**Baxter et al., 2018b**	**Dawson et al., 2021**	**de Jong et al., 2021**	**El-Kazaz and Hafez, 2020**	**Jacobs et al., 2021**	**Knierim, 2013**	**Ma et al., 2020**	**Monckton et al., 2020a**	**Schwean-Lardner et al., 2012**	**Sultana et al., 2013**	**Vasdal et al., 2019b**	**Ventura et al., 2012**	**Wallenbeck et al., 2016**	**Yang et al., 2021**	**Data points per behaviour**
		%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**n**
Standing	Stationary		3.7	14.5		3.5	14.9	8.9		15.9	24.1		3.8	8.3		10.3	21.0		**11**
Sitting	Stationary		46.5	24.9	56.8	64.0	53.9	68.4		81.9	41.4		57.2	65.0		46.0	57.0		**12**
Walking	Active		2.7	1.5		1.8		14.5		2.2	6.1		3.7		11.8	6.5			**9**
Foraging incl. scratching	Active		5.0		0.7	0.3			12.0	4.2		19.0			9.6	2.7	2,5		**9**
Dustbathing	Active			13.6		0.7			1.9			15.0	0.5		3.6		0.0	12.0	**8**
Preening	Active		6.3	1.3	8.1			3.6	8.0		0.9		6.1			3.4	40.9		**9**
Wing/Leg stretching	Active							5.8	4.0	3.2	0.4		0.6		2.8		24.4		**7**
Wing flapping	Active									1.2					2.8		11.3	14.0	**4**
Drinking/Eating	Stationary	18.7	16.0	4.8		8.2	12.8	17.1	13.0		25.2		20.6	24.6		15.3	16.0		**12**

Calculation of minimum, stabilised minimum, median, mean, stabilised maximum, maximum, optimum, stabilised optimum of proportion of birds showing the selected behaviours

Table C.2: For each behaviour, the label and the following values of the proportion of birds performing a behaviour are given; minimum, stabilised minimum (median of the two lowest values), median, mean, maximum, stabilised maximum (median of two highest values) are given. Based on these values, in the optimum approach the median of the neutral behaviours was combined with the maximum of the positive behaviours, whereas in the stabilised optimum, the median of the neutral behaviours was combined with the stabilized maximum of the positive behaviours

Behaviour	Label	Min	Stabelized Min	Median	Mean	Max	Stabelized Max	Optimum (neg=min, neutral=median, pos=max)	Stabilised Optimum (neg=min, neutral=median, pos=max)
		%	%	%	%	%	%	%	%
Standing	Stationary	3.5	3.6	10.3	11.7	24.1	22.6	10.3	10.3
Sitting	Stationary	24.9	33.2	56.9	55.3	81.9	75.2	56.9	56.9
Walking	Active	1.5	1.7	3.7	5.7	14.5	13.1	14.5	13.1
Foraging incl. Scratching	Active	0.3	0.5	4.2	6.2	19.0	15.5	19.0	15.5
Dustbathing	Active	0.0	0.2	2.8	5.9	15.0	14.3	15.0	14.3
Preening	Active	0.9	1.1	6.1	8.7	40.9	24.5	40.9	24.5
Wing/leg stretching	Active	0.4	0.5	3.2	5.9	24.4	15.1	24.4	15.1
Wing flapping	Active	1.2	2.0	7.1	7.3	14.0	12.7	14.0	12.7
Drinking/Eating	Stationary	4.8	6.5	16.0	16.0	25.2	24.9	16.0	16.0

Standardisation to 100% in total of medians, means, optimum and stabilised optimum of proportion of birds showing the behaviours

Table C.3: The behaviours have been standardized to 100 % in each approach of the model. Given are selected behaviours, their label, the median, mean, optimum and stabilised optimum

Behaviour	Label	Median	Mean	Optimum	Stabelised optimum
		%	%	%	%
Standing	Stationary	9.3%	9.5%	4.9%	5.8%
Sitting	Stationary	51.6%	45.0%	27.0%	31.9%
Walking	Active	3.4%	4.6%	6.9%	7.4%
Foraging incl. Scratching	Active	3.8%	5.1%	9.0%	8.7%
Dustbathing	Active	2.5%	4.8%	7.1%	8.0%
Preening	Active	5.5%	7.1%	19.4%	13.7%
Wing/leg stretching	Active	2.9%	4.8%	11.5%	8.4%
Wing flapping	Active	6.4%	6.0%	6.6%	7.1%
Drinking/Eating	Stationary	14.5%	13.0%	7.6%	9.0%
Sum		**100.0%**	**100.0%**	**100.0%**	**100.0%**

Data extraction space covered and the corresponding weight

Table C.4: The table reports the extracted and recalculated data for the space covered of an broiler. Given is the behaviour and the corresponding label and the extracted data from four different references. In addition (grey-lettered part), the mean of the values for standing and sitting/resting as well as a ratio of the mean space covered of laying hens for these two behaviours (see LAYER SO) was calculated resulting in a conversion factor. This conversion factor was applied to the other space data of the laying hens resulting in a recalculated space covered by broilers to extend the data base of the model regarding the selected behaviours (N). To calculate stocking density in line with the data extracted for the space covered, also the corresponding weight of the animals is given

Behaviour	Label	(Giersberg et al., 2016)	(Spindler et al., 2016)	(Habig et al., 2016)	(Bokkers et al., 2011)	mean broilers	mean layers	conversion factor	data layers	recalculated based on conversion ratio	Data points
		cm^2	cm^2	cm^2	cm^2	cm^2	cm^2		cm^2	cm^2	N
Standing	Stationary	367.12	359.27	528.00	638.40	473.20	505.19	0.94			4
Sitting/ Resting	Stationary	386.92	385.93	578.00	636.15	496.75	522.14	0.95			4
Walking	Active	2*Standing									0
Foraging	Active				609.40				856.00	808.10	2
Dustbathing	Active				728.20				1098.00	1036.50	2
Preening	Active				651.80				1150.00	1085.60	2
Wing/leg stretching	Active				702.00				893.00	843.00	2
Wing flapping	Active								2387.83	2254.20	1
Drinking/ Eating	Stationary				642.30				505.19	476.90	2
Weight [kg]		2.335	2.296	3.856	2.468						

Data extraction of interindividual distance

Table C.5: The table reports on the selected behaviours, their label, as well as the interindividual distance which are part of the behavioural space model. Regarding the calculation of the circle reflecting the chicken, the area a represents the mean space covered per behaviour in cm^2, d is the diameter and r the radius after converting the space into a circle (see Section 2.3.2.1 for details). To this circle (space covered by a chicken expressing a specific behaviour), the interindividual distance was added. From one reference, interindividual distances for each behaviour were extracted and converted into a radius

Behaviour	Label	Chicken-circle			Distance-circle		
		area	diameter	radius	Distance	Radius	Area
		a (Mean)	d	r	D (Buijs et al., 2011)	R	A
		cm^2	cm	cm	cm	cm	cm^2
Standing	Stationary	473.2	24.5	12.3	22.3	11.2	1723.6
Sitting/Resting	Stationary	496.8	25.1	12.6	23.3	11.7	1843.6
Walking	Active	946.4	34.7	17.4	22.9	11.5	2606.9
Foraging	Active	708.7	30.0	15.0	23.3	11.7	2234.5
Dustbathing	Active	882.4	33.5	16.8	24.3	12.2	2625.5
Preening	Active	868.7	33.3	16.6	25.3	12.7	2693.2
Wing/leg stretching	Active	772.5	31.4	15.7	26.3	13.2	2611.4
Wing flapping	Active	2254.2	53.6	26.8	27.3	13.7	5136.9
Drinking/Eating	Stationary	559.6	26.7	13.3	24.4	12.2	2050.3

11. Calculation of space covered by a chicken (area α)

12. Multiplication of the space covered with mean, median, optimum and stabilised optimum of the proportion of a specific behaviour

Table C.6: This table reports the final outcome of the behavioural space model. The total area a chicken covers in cm^2 is given for each behaviour selected. The frequencies that each behaviour is expressed are combined with the space needed to express this behaviour. The outcome is a space profile reflecting a high-performing broiler in an improved environment. The sum of space needed per modelling approach is related to 1 m^2. The outcome is a specific number of chickens per m^2 and a specific stocking density (based on the mean weight of a broiler) given in kg per m^2, respectively

Behaviour	Label	Total area								
		per chicken	Behaviour							Calculation
		Alpha	Median	Mean	Optimal	Stabilized optimal	Median	Mean	Optimal	Stabilized optimal
		cm^2	%	%	%	%	cm^2	cm^2	cm^2	cm^2
Standing	Stationary	1,900.5	9.3%	9.5%	4.9%	5.8%	177.5	181.4	92.8	109.7
Sitting/Resting	Stationary	2,032.8	51.6%	45.0%	27.0%	31.9%	1049.3	915.4	548.5	648.6
Walking	Active	2,874.6	3.4%	4.6%	6.9%	7.4%	97.5	132.4	197.4	211.8
Foraging	Active	2,463.9	3.8%	5.1%	9.0%	8.7%	94.3	124.9	222.0	214.1
Dustbathing	Active	2,895.1	2.5%	4.8%	7.1%	8.0%	72.2	139.6	205.9	232.3
Preening	Active	2,969.6	5.5%	7.1%	19.4%	13.7%	163.8	211.4	575.5	407.8
Wing/leg stretching	Active	2,879.5	2.9%	4.8%	11.5%	8.4%	83.6	137.7	332.4	243.0
Wing flapping	Active	5,664.2	6.4%	6.0%	6.6%	7.1%	362.4	338.6	376.0	401.9
Drinking/Eating	Stationary	2,260.8	14.5%	13.0%	7.6%	9.0%	328.1	295.0	171.5	202.8
			Weighted average							
Total area per chicken							2,428.7	2,476.4	2,721.9	2,672.1
No. chicken per m^2							**4.1**	**4.0**	**3.7**	**3.7**
kg per/m^2	mean 2,739						**11.28**	**11.06**	**10.06**	**10.25**

Derivations

Based on the stabilized optimal model, further pictures can be generated showing how many birds can show a certain behaviour on 1m^2 at the same time (excluding further space for additional animals) and how many birds would show a behaviour under scan sampling in the case of a stocking density of 42 kg/m^2, as this is the maximum stocking density currently allowed in the EU. For example, given 1m^2 of space, approx. 2 birds could flap their wings at the same time giving no additional space for any other birds. This picture does not take into account that behaviours are often socially facilitated and synchronized (see Table C.7).

Table C.7: Additional pictures are given to show how many birds simultaneously could perform a behaviour or how a random scan sample of flock in m^2 with a max. stocking density of 42 kg would look alike vs a random scan sample of a 'optimum stabilized' flock with a stocking density of 10.25 kg

Behaviour	How many birds could simultaneously perform the behaviour in 1 m^2 (excluding any other birds)?	How many birds would perform the behaviour given a stocking density of 42 kg/m^2 (scan sample of flock)?	How many birds would perform the behaviour given a stocking density of 10.25 kg/m^2 (scan sample of flock)?
Standing	5.3	0.89	0.22
Sitting/ Resting	4.9	4.89	1.19
Walking	3.5	1.13	0.28
Foraging	4.1	1.33	0.33
Dustbathing	3.5	1.23	0.30
Preening	3.4	2.11	0.51
Wing/leg stretching	3.5	1.29	0.32
Wing flapping	1.8	1.09	0.27
Drinking/ Eating	4.4	1.38	0.34
Sum of animals		**15.34**	**3.74**

Appendix D – Assessment of ABMs collected in slaughterhouses to monitor the level of welfare on broilers farms

The starting point was a list of 14 ABMs (3 assessed *ante-mortem* and 11 *post- mortem*) as potentially relevant for measurement at slaughter in broiler chickens. These ABMs and their descriptions were identified by EFSA experts based on the existing literature (Welfare Quality®, 2009; EFSA AHAW Panel, 2012) and for each ABM the preferred time of assessment (i.e. *ante-* and/or *post-mortem*) was also proposed. To gather information on their use in practice, the 14 ABMs were discussed by the EFSA scientific National Contact Points (NCPs) network meeting (2021)[21] in the context of an exercise during the annual Network meeting (for the list of ABMs, their description, full details on methodology and results of this exercise, see EFSA, 2021).

In addition to the initial list of 14 ABMs, based on EFSA expert opinion, 'dirtiness' and 'total mortality on farm' and 'wounds' were added in the *ante-mortem* assessment. For the complete list of ABMs assessed under this Specific ToR see Table D.1.

Table D.1: Starting list of ABMs potentially relevant to collect in slaughterhouses for monitoring the level of welfare on broiler farms and indication of the preferred time of assessment (*ante-* or *post-mortem*)

ABMs in broilers			
ante-mortem		***post-mortem***	
1	Dirtiness[(a)]	1	Breast blister
2	Total mortality (on farm)[(a)]	2	Carcass condemnation[(b)]
3	Wounds[(a)]	3	Cellulitis
4	General health conditions	4	Emaciation
5	Dead on arrival	5	Footpad dermatitis
6	Abnormal behaviour	6	Hock burn
		7	Plumage damage
		8	Wounds
		9	Bruises
		10	Ascites
		11	Red or inflamed skin

(a): Added by EFSA Working group experts.
(b): 'Indicators used for carcass condemnation' in EFSA, 2021.

[21] The scientific NCPs Network is composed by the EU MS (including EFTA Countries) National Contact Points that provide scientific support under Art 20 of Reg. (EC) 1099/2009 on the protection of the animals at the time of killing (scientific NCPs).

From the ABMs listed in Table D.1 a semi-quantitative consensus exercise was carried out to identify those ABMs that could best represent the overall animal welfare conditions in the farm. The exercise consisted of two steps: (i) Screening of ABMs; (ii) Selection of ABMs (see Figure D.1).

The Screening was carried through an Experts' opinion exercise on the initial list of ABMs, on the basis of four (screening) criteria (i.e questions to answer with a Yes/No option):

1) Relevance to animal welfare: *Is the ABM relevant to the welfare consequences defined in this opinion, and not only to production and meat quality aspects?*
2) Relationship with the farm (and not transport or lairage): *Is the ABM indicative of a welfare consequence of the farm and not caused or masked by transport, lairage and slaughter?*
3) Existing data in literature: *Do scientific publications describe the ABM detailing methodologies, prevalence and the relation with on-farm welfare consequences?*
4) Feasibility for large scale collection: *Is the ABM already routinely collected or there is evidence that it could be collected in a national programme?*

As precautionary principle, if consensus was not reached, the criterion was considered a 'Yes'. Only ABMs that received a 'Yes' for all criteria passed to the second step (Selection).

The Selection step consisted of a ranking of the ABMs based on four criteria presented below. This was followed by expert's selection of those with the highest ranking.

The four criteria were:

1) Welfare consequences (C1): the experts identified which welfare consequences on farm (from the list in Section 3.4.1) could be associated with the selected ABM. They scored the ABM according to the number of different welfare consequences selected.
2) Technology readiness (C2): each ABM was evaluated for the known level of readiness of an automated system to be adopted by the market, based on the technology readiness scale (Mankins, 1995).
3) Already used at slaughter (C3): the ABMs were scored according to the answers received from the exercises of the scientific NCPs Network (EFSA, 2021).
4) Priority given by the Network (C4): the ABMs were scored according to the answer received from the scientific NCPs Network exercise (EFSA, 2021).

For each of these criteria, the EFSA experts agreed on a score from 0 to 4, where '0' means absence and '4' the highest score.

Finally, a weight was attributed by expert consensus to each criterion according to its importance in answering the request of the mandate. The allocated weights were: C1 = 6.5; C2 = 1.5; C3 = 1; C4 = 1.

A final score (weighted score) was calculated following the formula below:

$$\text{Weighted score} = \frac{(\text{score}_{C1} * \text{weight}_{C1}) + (\text{score}_{C2} * \text{weight}_{C2}) + (\text{score}_{C3} * \text{weight}_{C3}) + (\text{score}_{C4} * \text{weight}_{C4})}{\sum_{C4}^{C1} \text{weights}}$$

The full process leading to the final list of ABMs that were selected is summarised in Figure D.1.

Figure D.1: Flow chart of the process leading to the selection of the ABMs that were considered to best reflect animal welfare in broiler chickens farm

Appendix E – Measurement of ABMs

Situation 1: The objective is to assess the prevalence (i.e. proportion) of birds in a flock with a specific ABM (e.g. 'wound', 'feet lesion'). Then, to calculate the sample size, the following data will be needed:

1) The population size: total number of birds in the flock
2) The expected prevalence (if not known, rather pick up a low value)
3) The relative precision: the accuracy to achieve
4) Confidence level: usually used at 95%

As an example: if the objective is to assess, in a flock of 20,000 laying hens, an expected prevalence of feet lesions of 1% with 30% relative precision (it means that the result will be something like $1 \pm 0.3\%$) and 95% confidence level, the sample needed will be 4,226 animals (see Table E.1). If the objective is to assess the level of wound that is expected to be around 20%, with a relative precision of 50% ($20 \pm 10\%$), it will be needed to observe 62 birds.

Situation 2: The objective is to detect if the prevalence in the flock is above or below a certain 'level' called design prevalence (e.g. check if dirty broilers do not exceed 1% of animals).

Table E.1: Size of the sample according to expected prevalence and relative precision expected (example of a population of 20,000 and for sensitivity and specificity of the ABM of 100%)

Precision, %	Expected prevalence, %								
	1	2	3	4	5	10	15	20	25
10	19,404	18,824	12,422	9,220	7,300	3,458	2,177	1,537	1,153
20	9,508	4,706	3,106	2,305	1,825	865	545	385	289
30	4,226	2,092	1,381	1,025	812	385	242	171	129
40	2,377	1,177	777	577	457	217	137	97	73
50	1,522	753	497	369	292	139	88	62	47
60	1,057	523	346	257	203	97	61	43	33

Then to calculate the sample size, the following data will be needed:

1) The population size: total number of birds in the flock
2) The prevalence threshold
3) The confidence interval: usually used at 95%

As an example: the number of birds in the flock is approx. 10,000 and the objective is to determine if the prevalence of dirty broilers in the flock is over 1% or not. In this case, 294 animals will have to be scored and if no animal is scored dirty that the prevalence in the flock is below 1%.

Table E.2: Size of the sample according to the prevalence that is meant to be detected and the flock size (valid for sensitivity and specificity of the ABM of 100%)

Threshold, %	Total number of birds in the flock					
	200	500	1,000	5,000	10,000	20,000
0.5	190	349	450	564	581	589
1	155	225	258	290	294	296
2	105	129	138	147	148	148
3	78	90	94	98	98	99
4	62	69	71	73	74	74
5	51	56	57	59	59	59
10	27	28	29	29	29	29

The bigger the population size, the least effect it has on the sample size.