EXTERNAL SCIENTIFIC REPORT

Scientific report updating the EFSA opinions on the welfare of broilers and broiler breeders[1]

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ABSTRACT

The EFSA AHAW panel is requested to develop several scientific opinions concerning animal based measures to assess the welfare of livestock animals. The main objective of this report is to review the broiler welfare literature to identify gaps and potential areas to strengthen and update three SCAHAW and EFSA opinions: i) The welfare of chickens kept for meat production (broilers) (SCAHAW, 2000), ii) Influence of genetic parameters on the welfare and resistance to stress of commercial broilers (EFSA, 2010), iii) Welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes (EFSA, 2010). The literature review was done by a group of authors and reviewers, under the supervision of an editorial team. A large number of new scientific references are quoted. Regarding the first and oldest opinion, this review presents 47 amended and new conclusions. In addition, it suggests twelve new recommendations and proposes a list of hazards. Especially the paragraphs on behavioural restriction, light, stocking density and environmental enrichment are updated with new information from a large number of new scientific references. Regarding the second opinion, nine new conclusions are proposed. Recommendations of the previous EFSA report are further supported by new information, and one new recommendation is a suggestion to further study the role of incubation conditions on welfare issues such as gait abnormalities, thermal discomfort and ascites. A limited number of new hazards are proposed. Regarding the third opinion, four new conclusions are proposed. Recommendations of the previous EFSA report are also in this case further supported by new information. One new recommendation is a suggestion to further study the impact of management on forced mating behaviour. A couple of new hazards are proposed.

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SUMMARY

The EFSA Animal Health and Welfare panel is requested to develop several scientific opinions concerning animal based measures to assess the welfare of livestock animals. The main background documents for these mandates are the EFSA Scientific Opinions on the welfare of livestock and the Welfare Quality® assessment protocols. EFSA has issued 3 scientific opinions on different aspects related to the welfare of broilers. These were i) a scientific opinion on the welfare of chickens kept for meat production (broilers), developed in 2000 by the former Scientific Committee on Animal Health and Animal Welfare (SCAHAW), and two EFSA scientific opinions, issued in 2010: ii) The influence of genetic parameters on the welfare and the resistance to stress of commercial broilers and iii) Welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes. The terms of reference (ToRs) of the Commission mandates on animal based measures to assess the welfare of livestock animals suggest that such measures could be used to check whether the recommendations listed in the EFSA scientific opinions have been fulfilled or not. It is therefore important that conclusions and recommendations of the EFSA scientific opinions are up to date.

The three scientific opinions are evaluated in one report. The main objective of the report is to carry out preparatory work for the mandate on animal-based measures for assessing broiler welfare. It is a review of the literature provided in the opinions in order to identify gaps and potential areas to strengthen or amend the conclusions and recommendations of these opinions. It also aims at identifying hazards that may be revised by the AHAW Panel in light of the newly available scientific evidence. The present report addresses the three opinions referred to above, presented here as chapters 1, 2 and 3 (sub-reports A, B, and C) respectively.

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

Databases searched included ISI Web of Knowledge (all databases, i.e. Web of Science, Current Contents Connect and Medline) and CAB Abstracts. General searches were conducted on broiler welfare as of (and including) the year 2000 and onwards using the key words broiler*, chick*, poultry*, welfare. More specific searches using other key words were conducted when only a few references were initially found for a certain topic.

For chapter 1 (sub-report A), 'Update of the welfare of chickens kept for meat production (broilers)', 47 amended and new conclusions are proposed. Especially the paragraphs on behavioural restriction, stocking density, environmental enrichment and light are updated with new information. Some examples of new or amended conclusions related to these paragraphs are: i) selection for increased growth impedes the activity level of broilers; ii) enrichment strategies may alleviate behavioural restriction of broilers by increasing locomotion and preventing disturbance of rest; iii) although high stocking density has a negative influence on many aspects of broiler welfare, it is unclear to what extent these are in fact attributable to environmental factors that deteriorate with increased density

(temperature, humidity, litter moisture). Also, it is unclear to what extent it is possible to prevent such a deterioration using improved climatic control, since air may be trapped between birds when they are stocked densely; iv) large variation in environmental factors may obscure density effects studied in the field. However, even studies on commercial farms showed a decrease in growth rate and walking ability as stocking density increased, and increased disturbance of rest, as well as an increase in skin scratches, hock burn and foot pad dermatitis as stocking density increased. These effects are all indicative of decreased welfare; v) enrichments are additions to the birds' environment that improve the welfare of the birds, e.g., by providing birds with cover, or by encouraging activity and desirable behaviours like perching. Perches should be considered as potential enrichment, although their use depend on factors like breed or especially perch design. Low horizontal barriers show particular promise in encouraging perching behaviour in fast growing strains; vi) although enrichment is a promising area for research to improve broiler welfare, benefits should not be generalized, as results of the intervention may depend on multiple factors. Further research is needed to refine enrichment design in such a way that materials used are long lasting, easy to disinfect among successive flocks and are easy to apply; vii) behaviour patterns of broilers are influenced by the contrast in intensity between the light and dark periods, as well as by the absolute light intensity level in the dark and light periods respectively. The effect of contrast in light intensity on broiler welfare needs further research; viii) since the four aspects of light (photoperiod, intensity, light source and wavelength) interact with one another they cannot be considered independently. Thus, regulations or codes designed to standardise light levels need to take account of the fact that broilers may perceive the luminance from different light sources differently. In addition, it is important to consider not only daytime illumination levels, but night time illumination levels and the intensity contrast between the two. In addition to the new and amended conclusions, many recommendations are updated and twelve new recommendations are proposed. These are presented in a table together with a list of proposed associated hazards.

For chapter 2 (sub-report B) on 'update of influence of genetic parameters on the welfare and the resistance to stress of commercial broilers' nine new conclusions were formulated. These are i) there are some indications that incubation conditions may affect leg health, but further research is necessary; ii) gait score is widely used to assess broiler leg health in commercial flocks. However, gait score cannot discriminate between underlying pathology or poor gait due to conformation; iii) because of the relationship with management factors, flock health and the fact that foot and hock lesions are likely to be painful, FPD and hock burns are useful welfare indicators in broilers; iv) hock and foot lesions likely have a partially different aetiology, where hock lesions are not only related to wet litter and ammonia concentrations in the litter (like FPD) but also to the weight of the birds; v) diet composition may affect the incidence of ascites; vi) the brooding process may affect the incidence of ascites post-hatching; vii) low energy intake can decrease the incidence of SDS and ascites because of a slower growth rate; viii) brooding conditions may affect the ability of the animal to cope with heat stress later in life; iv) suboptimal digestibility of feed may have a negative effect on litter quality and in this way affect the cleanliness of the birds and the incidence of contact dermatitis. Recommendations of the previous EFSA report are further supported by new information. One new recommendation was the suggestion to further study the role of incubation conditions on welfare issues such as gait abnormalities, thermal discomfort and ascites. A couple of new hazards are proposed and the evidence behind many already identified hazards was strengthened.

For chapter 3 (sub-report C) 'Update on welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes' four new conclusions were formulated. These are i) the use of diets with a high proportion of insoluble fibre may alleviate the sensation of hunger during rearing; ii) improved management protocols (such as reducing stocking density or using environmental enrichment) can be used to improve mating behaviour, reducing the frequency of force matings; iii) infrared trimming likely offers welfare and performance advantages over hot-blade trimming (according to studies in laying strains); iv) reduction of stocking density may reduce feather damage and have positive effects on behaviour and hen performance. Recommendations of the

previous EFSA report are further supported by new information. One new recommendation is the suggestion to further study the impact of management on forced mating behaviour. A number of new hazards are proposed and the evidence for existing hazards was strengthened.

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BACKGROUND

The EFSA AHAW Panel is requested by the EU Commission to develop several scientific opinions concerning animal-based measures to assess the welfare of livestock animals. Mandates on dairy cows, pigs, calf and beef cattle have already been received from June 2010 onwards. A further mandate to develop a scientific opinion on animal based measures for broilers was received on June 10th 2011.

The main background documents for this mandate are a scientific opinion on The welfare of chickens kept for meat production (broilers), developed in 2000 by the former Scientific Committee on Animal Health and Animal Welfare (SCAHAW), and two EFSA scientific opinions, issued in 2010, on different aspects related to genetic selection of broilers: i) The influence of genetic parameters on the welfare and the resistance to stress of commercial broilers (2010a) and ii) Welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes (2010b).

The European Commission requests to: 1) identify how animal-based measures could be used to ensure the fulfilment of the recommendations of EFSA scientific opinions on the welfare of broilers; 2) identify how the Welfare Quality® assessment protocols cover the main hazards identified in EFSA scientific opinions (and vice-versa) and, where necessary, how other scientific information can be used to cover these hazards; 3) identify which relevant animal welfare issues cannot be assessed using animal-based measures for broilers and what kind of alternative solutions are available to improve the situation; and 4) list main factors in the various husbandry systems which have been scientifically proven to have negative effects on the welfare of broilers.

The terms of reference (ToRs) of the Commission mandates on animal-based measures to assess the welfare of livestock animals suggest that such measures could be used to check whether the recommendations listed in the EFSA scientific opinions are fulfilled or not. It is therefore important that conclusions and recommendations of the EFSA scientific opinions are up to date.

TERMS OF REFERENCE AS PROVIDED BY EUROPEAN FOOD SAFETY AUTHORITY

This contract was awarded by EFSA to: Stichting Dienst Landbouwkundig Onderzoek

Contract title: Preparatory work for the future development of animal based measures for assessing the welfare of broilers

Contract number: CT/EFSA/AHAW/2011/06

OBJECTIVES

The main objective of this report is to carry out preparatory work for the mandate on animal-based measures for assessing broiler welfare. It is a review of the literature provided in the scientific opinions in order to identify gaps and potential areas to strengthen or amend the conclusions and recommendations of such opinions.

The specific objectives of the report are as follows:

- To review the relevant scientific literature from 2000 onwards and gather newly available scientific evidence on the welfare of broilers. For this review, the information in the previous reports (a) The welfare of chickens kept for meat production (broilers) (SCAHAW, 2000), and (b) the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers (EFSA, 2010) has been thoroughly reviewed and updated.

- Propose possible amendments to the conclusions and recommendations of the SCAHAW scientific opinion on 'the welfare of chickens kept for meat production (broilers)' from 2000 in light of the new scientific evidence.

- Propose a consolidated list of welfare hazards based on the outcome of two EFSA scientific opinions on the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers and on welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes from 2010 in light of new scientific evidence. To this purpose, also the information in the report on the welfare aspects of the management and housing of the grand-parent and parent stock raised and kept for breeding purposes (2010) has been thoroughly reviewed and updated.

The focus of the report is on science-based knowledge that is important for decision makers, in particular scientific knowledge and advice (recommendations) that specifies how broiler welfare may be monitored and improved in Europe in the (near) future, and that has become available after the publication of the underlying reports (or which revises them).

METHODS

The editors of this report used a step-wise iterative approach in which they involved several experts from different research institutes.

Step 1

An initial literature search resulted in a large number of abstracts, which were screened for relevance to the present report by the editorial team. The screening of literature is described in one of the paragraphs below. The abstracts were allocated to chapters presented in the original EFSA reports.

Step 2

Authors were recruited and they were sent one or more paragraphs and the abstracts selected in Step 1. They were asked to add their expertise, any missing references and statements, and to develop this into texts for each paragraph. A total of 16 co-authors contributed in this step of the process. They remained anonymous throughout this and the following steps.

Step 3

The draft paragraph texts were then sent to 'first reviewers'. These reviewers received several paragraphs of each report and developed the texts further. They provided additional expertise or references. Altogether nine 'first reviewers' completed their work.

Step 4

Was similar to step 3, but included five 'second reviewers'. They were asked to do the same as the first reviewers.

Step 5

The editorial team had a look at the text and proposed a list of amended conclusions and recommendations, as well as an updated list of hazards based on the original EFSA/SCAHAW reports.

Step 6

All authors and reviewers were asked to have a final look at the sub-report they contributed to, and to suggest improvements. In addition, they were asked to contribute to the amended conclusions and the recommendations section of the report.

Step 7

In the final step the editorial team had their final look at the text, list of amended conclusions, recommendations and hazards.

LITERATURE SEARCHES

The literature searches conducted at the beginning of this project resulted in 1257 unique references. Database searched was ISI Web of Knowledge (all databases, i.e. Web of Science, Current Contents connect and Medline). General searches were conducted on broiler welfare as of (and including) 2000 using the key words broiler*, chick*, poultry*, welfare. Including key-words stress* and behavio* resulted in more than 10.000 records which was not feasible to screen. More specific searches were conducted with key-words as listed below, especially when initially only a few references were found for a certain topic. For the specific searches, ISI Web of Knowledge as well as CAB abstracts were used as databases. This could result in duplicate references in the Endnote selection of records and therefore a screening for duplication was performed after the literature search.

Technical details of the general search

ISI web of knowledge [conducted 1-11-2011]: Topic=(broiler* OR chick* OR poultry) AND Topic=(welfare), Timespan=2000-2011. Databases=all.

Specific searches related to sub-report A and B (broilers)

ISI web of knowledge [conducted 1-11-2011]: Topic (broiler* OR chick* OR poultry) AND Topic=Abnormal behavio*. Timespan 2000-2011. Databases=all.
Topic (broiler* OR chick* OR poultry NOT broiler breed*) AND Topic=feed restrict*. Timespan 2000-2011. Databases=all.

CAB abstracts [conducted 2-11-2011]: (broiler* OR chick* OR poultry) AND enrichment AND behavio*; (broiler* OR chick* OR poultry) AND imprinting AND behavio*;

(broiler* OR chick* OR poultry) AND odour AND behavio*. All keywords in [Ab]. Timespan 2000-2011. Publication type: all.

CAB abstracts [conducted 2-11-2011]: (broiler* OR chick* OR poultry AND Ascites OR Sudden death syndrome OR Spiking mortality syndrome; (broiler* OR chick* OR poultry) AND mortality; (broiler* OR chick* OR poultry) AND ammonia AND pathology; (broiler* OR chick* OR poultry) AND dust AND pathology. All keywords in [Ab]. Timespan 2010-2011. Publication type: all.

CAB abstracts [conducted 3-11-2011]: (broiler* OR chick* OR poultry) AND slow grow* AND behavio* (2010 onwards); (broiler* OR chick* OR poultry) AND genetic select* AND behavio* (2010 onwards); (broiler* OR chick* OR poultry) AND lameness (2010 onwards); (broiler* OR chick* OR poultry) AND tibial (2010 onwards); (broiler* OR chick* OR poultry) AND valgus (2010 onwards); (broiler* OR chick* OR poultry) AND myopathy* OR muscular dystroph* (2010 onwards); (broiler* OR chick* OR poultry) AND skeletal disorder (2010 onwards); (broiler* OR chick* OR poultry) AND breed* AND welfare. All keywords in [Ab]. Timespan 2010-2011. Publication type: all.

CAB abstracts [conducted 10-11-2011]: Animal welfare [Ab] AND definition [Ab]. Timespan 2000-2011. Publication type: all.

ISI Web of knowledge [conducted 10-11-2011]: Topic=(broiler* OR chick* OR poultry OR fowl) AND Topic=stress indicator* AND Topic= measur*. Timespan 2000-2011.

CAB abstracts [conducted 14-11-2011]: (broiler* OR chick* OR poultry) AND (drinking nippl* OR drinker* OR nutrition* OR feed restrict* OR meal feed*) AND welfare. Timespan 2000-2011. Publication type: all.

Specific searches related to sub-report C (broiler breeders)

ISI web of knowledge [conducted 1-11-2011]: Topic=(broiler breed* OR parent stock*) AND Topic= housing OR management OR   mutilation* OR rearing OR culling OR transport OR slaughter OR alternative breed* OR alternative strain* or feed restrict* OR hunger* OR aggressi* OR behavio* OR enrichment* OR light OR ammonia OR dust OR contact dermatitis* OR foot pad lesion* OR pododermatitis OR leg weakness* OR cage OR peritonitis OR salpingitis OR metabolic disorder* OR infectious OR biosecurity* OR training* OR stockmanship*). Timespan 2010-2011. Databases: all.

CAB abstracts [conducted 02-11-2011]: same terms as listed above in [Ab] (abstract field). Timespan 2010-2011. Publication type: all.

THE REVISION OF THE HAZARDS LIST

Hazards are usually identified as causes or factors that affect animals' needs and that have a potential to change the animals' welfare. Although potentially both negative and positive changes could be accessed, only negative impacts were considered so far in risk assessment. These factors may also be more broadly described as 'conditions that may have a direct impact on the welfare and health of the animal studied'.

They are identified, by either applying welfare quality criteria, i.e. researching which factors have an impact on the criteria such as good feeding and more detailed absence of hunger or thirst for instance, or good health, absence of disease, pain or injuries. Another option is a more 'technical' approach by going systematically through all factors which may impact on the life of the animals, and consider whether these could lead to an impact on their welfare. This has been described in detail in previous

EFSA reports and technical reports to EFSA. In the light of new research, this list may change and will have to be updated regularly, even though it probably does not change drastically in a short period of time.

For chapters 2 and 3 (sub-reports B and C), most of the hazards identified in the course of this report were the same as in the previous EFSA opinions (EFSA, 2010b; a). However, more information is now available due to further research or sometimes hazards have been further refined or new hazards were identified, such as inappropriate incubation process and poor hatchery hygiene (chapter 2 - sub-report B). In the SCAHAW report on the welfare of chickens kept for meat production (SCAHAW, 2000) no hazards were identified. We now composed a hazard list related to the updated paragraphs and recommendations in chapter 1 (sub-report A). This hazard list in chapter 1 (sub-report A) was based on the hazards defined in chapters 2 and 3 (sub-report B and C).

At the end of each chapter a list will be provided of the hazards related to the (amended or updated) recommendations.

1.   Update of the welfare of chickens kept for meat production (broilers) - Sub-report A

This part updates the underlying report: The welfare of chickens kept for meat production (2000, available at http://ec.europa.eu/food/fs/sc/scah/out39_en.pdf).

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In general, the content of the report is based only on new available information since the editing of the original report (SCAHAW, 2000). Some of the experts thought it to be relevant to include (parts of) the original text in the update. When this is the case it is indicated under the heading of the specific paragraph.

The recent EFSA report on the influence of genetic selection on the welfare and the resistance to stress of commercial broilers (EFSA, 2010) already covered for some topics the relevant literature from 2000 onwards. Where applicable, the relevant section of sub-report B is referred to for updated information since 2010.

1.1. Welfare – definitions and measurements

1.1.1. The concept of animal welfare

Animal welfare has been defined in (SCAHAW, 2000). It comprises both physical and mental health. The assessment of farm animal welfare requires a good understanding of the animals' affective experience, including their emotions (Boissy et al., 2007).

Welfare of domesticated animals may be estimated by comparison with the wild ancestors, Red junglefowl (*Gallus gallus*), or with other breeds (*Gallus gallus domesticus*), e.g. laying hens, from the same species. Furthermore, welfare in relation to animals' motivation may be studied using time budgets, preference/choice studies or operant studies. However 'welfare' constitutes of more than the behaviour. Dawkins et al. (2004) estimated welfare of broilers by measurements of mortality, physiology, behaviour and health. Production is a relevant factor, however good production does not necessarily mean good welfare, whereas decreased production may be a warning sign.

Motivation and frustration of motivated behaviours is an important part of the welfare of an animal. Bokkers et al. (2007) found that the physical abilities of broilers is likely to reduce their ability to behave in accordance with their motivation.

1.1.2. The assessment of farm animal welfare

Broiler welfare was reviewed by Bessei (2006) and it was concluded that broiler welfare problems have several causes. These causes are the genetics of the birds which e.g. decreases their locomotor activity, skeletal abnormalities, high body weight, or the environment of the bird. The commercially used lighting programmes may also decrease locomotor activity. This low locomotor activity, caused by early and fast growth rate, is shifting the behavioural time budget of the birds towards extreme sitting levels, in combination with wet litter, causing skin problems such as breast blisters, foot pad dermatitis and hock burn. Under commercial conditions, litter was wetter when birds were housed at a higher stocking density (Dawkins et al., 2004).

Animal welfare is multidimensional. The assessment of animal welfare relies on complementary measures covering all dimensions. The European Welfare Quality® project constructed a multicriteria evaluation model for animal welfare assessment at the level of the farm or slaughterhouse. In the model four welfare principles were distinguished: good feeding, good housing, good health, and appropriate behaviour (Botreau et al., 2009; Welfare Quality®, 2009).

1.1.3. The assessment of welfare in broilers

1.1.3.1. Mortality and morbidity

Dawkins et al. (2004) reported mortality levels ranging from 1.4–14.7 % in commercial flocks, and in their study stocking density varied from 30-46 kg/ m2. Interestingly, stocking density did not affect mortality significantly, but rather the environment in the house had the largest impact on mortality.

1.1.3.2. Body condition and reproduction

No new information.

1.1.3.3. Behaviour

It has been highly documented that (fast growing) broilers show high levels of sitting behaviour compared to laying hens (Bessei, 1992) or to slower growing strains of broilers of the same age (Bokkers and Koene, 2003a). Because of the weight and physical ability of broilers it is difficult to investigate their motivation for e.g. locomotor activity. A review by Rutten et al. (2002) gave some insight into the difficulty of using standard research methodology to investigate broiler motivation. Broiler voluntary walking increased significantly when some of the body weight was lifted by using a special suspension device on the birds (Rutten et al., 2002). Therefore it may be concluded that broilers might be motivated to move more but are physically unable to do so (see also 1.4.9 behavioural restriction).

Broilers show a different allocation of time to many behaviours compared to other breeds of *Gallus gallus domesticus,* and several studies have tried to encourage more natural behaviour of broilers through environmental enrichment. (Mench, 2001) used pens where the birds could scratch and perch and found that the complexity of broiler behaviour increased with enrichment. Furthermore (Arnould, 2001) enriched the environment of broiler chickens with strings and trays with sand, which increased the behavioural repertoire shown by the birds as well as general activity level. Studies on environmental enrichment are further discussed in 1.5.7.

Dustbathing is a highly motivated behaviour in *Gallus gallus domesticus* and hence has importance for the welfare of the birds. A study by (Shields et al., 2004) found that broilers up to the age of six weeks preferred sand as a dustbathing substrate. However, under experimental conditions broilers may also show dustbathing on wood shavings, the most commonly used litter substrate in modern broiler production (Bokkers and Koene, 2003a). Most likely litter quality also affect the birds' ability to dustbathe.

1.1.3.4. Physiology

No new information.

1.1.3.5. Assessment of broiler welfare

A review by Estevez (2007) mentioned tibial dischondroplasia, gait scores, carcass bruising and scratches as possible indicators of broiler welfare. Estevez (2007) also mentioned mortality due to heat stress. Some measurements may be used at the farm level, e.g. panting by birds (a sign of heat stress) and latency to lie (LTL) (Berg and Sanotra, 2003).

Animal welfare is multidimensional; its assessment therefore relies on complementary measures covering all dimensions. In the European Welfare Quality® project a multi-criteria evaluation model was constructed for welfare assessment at commercial farms or slaughterhouses. Four welfare principles are distinguished ('Good feeding', 'Good housing', 'Good health', and 'Appropriate behaviour') (Botreau et al., 2007). The following animal-based measures were included in the Welfare Quality® assessment protocol for broilers (Welfare Quality, 2009a): mortality and percentage of birds culled, cleanliness of the birds, foot pad dermatitis, hock burn, breast burn, percentage of birds panting or huddling, lameness, reason for rejection at slaughter (e.g., ascites, pericarditis, emaciated birds), fearfulness of humans (measured by the touch test), general behaviour of the flock (measured by the Qualitative Behaviour Assessment). In addition, resource-based measures such as stocking density, number of birds per drinker and litter quality are included in the assessment protocol.

1.1.3.6. Conclusions

1. For an adequate assessment of welfare a wide range of indicators must be used, although single indicators can show that welfare is poor. Animal welfare can be assessed in a scientific way and indicators of welfare include those of physiological states, behaviour and health.

2. The Welfare Quality® assessment protocol for broilers proposes a set of animal-based and resource-based measures to assess broiler welfare under commercial conditions.

1.2. Biology and behaviour of fowl/broiler

1.2.1. Characteristics associated with normal behaviour of fowl

Domestic fowl, as well as jungle fowl, are highly motivated to perform dust bathing and perching (Olsson, 2002; de Jong et al., 2007). The functional explanations for this are that these behaviours have had a strong influence on bird survival under natural conditions. Olsson (2000; 2002) demonstrated a high motivation for perching as well as frustration in the birds when they were prevented from perching at night. In 1.5.7.1. the use of perches in broilers is discussed further.

Dust bathing in broilers has not been observed to a large extent (Vestergaard and Sanotra, 1999) or in some studies not at all (Murphy & Preston, 1988). However Shields et al. (2004) and Bokkers and Koene (2003a) found that broilers do take a dust bath, in particular when given access to a suitable substrate, such as sand (Shields et al., 2004). Shields et al. (2004) tested birds until seven weeks of age and Bokkers and Koene (2003a) even to 12 weeks of age, demonstrating that even heavy broilers appear to be able to perform this natural behaviour.

1.2.2. Specific aspects of broiler biology and behaviour

There are a number of biological challenges for broilers. These have been extensively reviewed by Weeks (2004); Bessei (2006); Estevez (2007). These challenges include lameness, metabolic disorders, hock burn, sudden death syndrome, ascites, thermal discomfort and foot-pad dermatitis.

These challenges can in part be attributed to fast early growth rate and high stocking density, both driven by their great impact on profitability (Verspecht et al., 2011).

It is likely that motivation has not changed in accordance with the physical abilities of broilers, however the orientation ability may be lower in broilers compared to birds of a layer strain. In a study on bird orientation it was found that broilers were unable to use magnetic fields as orientation cues, whereas laying hen chick have this ability (Freire et al., 2008). However these results should be interpreted cautiously since they might not apply for all strains of broilers.

It has been suggested that genetic selection for high growth rate, with associated high body weight and poor leg condition, may have had such a negative impact on the physical ability of broilers that it hampers them in performing their behaviour even if they are motivated to do so. Some research has focused on investigating the intrinsic motivation in broilers. This is important for welfare reasons since a motivation which the bird cannot fulfil will lead to frustration and ultimately may cause stress and suffering. Bokkers and Koene (2004) compared fast and slow growing broiler strains and manipulated their motivation through feed deprivation. In the slow growing broilers motivation level affected time and success in completing a physical task with a food reward. However the fast growing broilers were sometimes unable to complete the task and showed behaviours indicative of frustration. Bokkers et al. (2007) found an effect of length of food deprivation on the motivation to perform a physically challenging task, although the reward size did not have an effect in this study. These studies suggest that impaired physical ability is the dominant restrictive factor for walking in birds with a high body weight, whereas in birds with a low body weight the motivation to move is the guiding factor for locomotion (see also 1.4.9 behavioural restriction).

1.2.3. Conclusion

1. For an adequate assessment of welfare a wide range of indicators must be used, although single indicators can show that welfare is poor. Animal welfare can be assessed in a scientific way and indicators of welfare include those of physiological states, behaviour and health.

2. The Welfare Quality® assessment protocol for broilers proposes a set of animal-based and resource-based measures to assess broiler welfare under commercial conditions.

1.3. Broiler production of today

1.3.1. Size and importance of broiler production

Broiler production is a large scale commercial operation in many countries of the world, with an estimated production of (at least) 20×10^9 broiler chicken produced annually, and 18×10^6 broiler breeder birds kept annually. The true global chicken population is not easy to measure, as the number of meat chickens kept in small numbers in subsistence and small scale farms and for local consumption is not easily estimated. Major producers are China, USA, EU, and Brazil, but significant commercial production occurs in many other countries as well (FAO STAT). Broiler production is at the current time (2012) seeing active growth, with an approximate increase in production volume of 35% between 2000 and 2008. Three major broiler companies dominate the genetics of commercial broiler production in terms of numbers of animals – these are; Cobb Vantress, Aviagen (Ros, Arbour Acres and Lohmann Meat strains) and Hubbard.

The total number of discrete broiler farm units in European production is small, as the average flock size in European production can be very large – with many commercial houses stocking birds at 10,000 to 20,000 animals or more in a single house. In some countries, a significant number of farms keep meat chickens under modified production systems – offering alterations in the system of production – free range (with access to outdoor areas, for example Label Rouge), increased space (reduced stocking density, for example retailer brands such as Tesco 'Willow'), increased space allowance, house enrichment and environmental enrichment (for example Freedom Food production), or production under the requirements of the EU organic regulation Council Regulation (EC) No 834/2007. In some countries broiler production is carried out to higher standards of animal welfare or meat quality. The target production characteristics as classified under these systems are described in formalised written standards which the producer must achieve before being permitted to market the birds under the specific product description. These 'standards' based production systems are usually linked to farm inspection and certification processes where the farm is inspected by an independent

body. It can only achieve certified status, and so sell its poultry as coming from the certified system, if the farm passes recognised standard requirements.

Overall, it is not appropriate to give a prescription for broiler production in the different EU member states as slaughter weight can vary from less than 1 kg to more than 3 kg and slaughter age from 21 to 170 days (Table 1). The genetic potential of the major broiler strains is optimized when the birds are slaughtered at between 2 and 2.2 kg, and this is the major weight banding for indoor reared broiler chicken in the EU (Cobb Broiler Management Guide 2010). Taking the mean body mass given in Table 1, the body weight at slaughter varies from 1440 to 2310 g. Age at slaughter varies more or less accordingly, with some countries using only fast growing genotypes and some others using slower growing ones to produce birds for specific market needs. Densities in commercial broiler houses are variable from relatively low (11 birds/m^2, 22.5 kg/m^2) to high (20 birds/m^2, 42 kg/m^2).

1.3.2. Legal regulations for broiler production

The recent broiler directive COUNCIL DIRECTIVE 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production sets stocking densities and characteristics of accepted broiler production in the EU. The regulatory provision within Directive 2007/43/EC regulates stocking density according to some prescribed limits:

1. A baseline stocking density of 33kgm^2;

2. Provision that chickens may be kept at a higher stocking density provided that the owner or keeper complies with the requirements of the directive set out in Annex 1 and Annex II – this being 39 kgm^2 for producers achieving the requirements of the Annex's and with a derogation permitting a maximum stocking density of 39 kgm^2 plus 3 kgm^2 (42 kgm^2).

The factors used to determine the capacity to stock at this maximum density in the EU are still under negotiation, but as an example, those proposed by the UK include analysis of data on 9 trigger factors collected at the farm and at slaughter (Tables 1 and 2).

Table 1: Trigger factors and levels to be used for Process 1: a trigger report is generated if the level of a post-mortem condition is exceptionally high (greater than 6 standard deviations above the mean), in that case State Veterinary Service – Animal Health will be alerted

Post-mortem condition	Process 1 trigger level (%)
Ascites/Oedema	2.02
Cellulitis & Dermatitis	3.00
Dead on Arrival	1.51
Emaciation	0.67
Joint lesions	0.43
Respiratory problems	9.28
Total rejections	11.76
Cumulative Daily Mortality	11.85
FPD score*	167

* The FPD score is not a percentage but is a score of the severity and extent of lesions (between 0 and 200) based on scoring 100 feet.

Table 2: Trigger levels to be used for Process 2: a trigger report is generated if the cumulative daily mortality rate is unusually high (greater than 3 standard deviations above the mean) and, additionally,

the rate of three or more post mortem conditions is high (above the mean). State Veterinary Service – Animal Health will be alerted.

Post-mortem condition	Process 2 trigger level (%)
Ascites/Oedema	0.21
Cellulitis & Dermatitis	0.20
Dead on Arrival	0.12
Emaciation	0.04
Joint lesions	0.02
Respiratory problems	0.49
Total rejections	1.11
FPD score*	60

* The FPD score is not a percentage but is a score of the severity and extent of lesions (between 0 and 200) based on scoring 100 feet.

Overall, for many broiler farms where the birds slaughter age is between 32 and 40 days, mortality typically varies between 0.75% per week and 1.32% per week, and most larger companies work to reduce overall mortality to less than 5% in the production period.

Despite the presence of EU Direction on broiler production systems, some countries currently make stipulations above those of the EU Directive – for example, in Sweden there is an Animal Welfare Programme for broilers, which was created as an agreement between the production advisors, veterinarians and the Swedish National Board of Agriculture. The procedure is to score the general standard of management, housing, facilities, equipment, and stockmanship on the broiler farms and within each broiler house. The maximum permitted stocking density in the Swedish system can vary between 20 and 36 kg/m² with the maximum of 25 birds/m². The higher densities are subjected to more stringent management quality measures, and these are assessed by independent auditors and regulated by the authorities concerned (Berg and Algers, 2004).

As an example the Freedom Food space and forage requirements are 'above' those of the Broiler Directive 2007/43/EC.

For chickens reared in the following systems, the stocking rate and density must never exceed, or be likely to exceed, the figures shown in Table 3 below.

Table 3: Space, stocking density and range requirements for meat chickens reared to Freedom Food standards (Freedom Food April 2011).

System of production		Indoor area		Minimum range area (m² of available range area/bird)
		No. chickens/m² of available floor space	kg/m² of available floor space	
Indoor		19	30	-
Free-range [a]		13	27.5	1
Organic [a]	fixed housing	10	21	4
	Mobile housing	16[b]	30	2.5[c]

[a] figures shown are those required by law, as set-out under either the Marketing standards for poultry meat Commission Regulation (EC) No. 543/2008 for free-range or the organic production of agricultural products European Council Regulation (EEC) No. 2092/91, as amended, for organic.

[b] only in the case of mobile housing not exceeding 150m² floor space which remain open at night.

[c] provided that the limit of 170kg of N/ha/year is not exceeded.

1.3.3. Rearing conditions

The following section sets out the Directive 2007/43/ EC requirements and subsequently a general description of broiler rearing in EU Member States. Broilers in the EU are kept on litter systems, and Directive 2007/43/ EC requires that:

- Drinkers. Drinkers shall be positioned and maintained in such a way that spillage is minimized.

- Feeding. Feed shall be either continuously available or be meal fed and must not be withdrawn from chickens more than 12 hours before the expected slaughter time.

- Litter. All chickens shall have permanent access to litter which is dry and friable on the surface.

- Ventilation and heating. Ventilation shall be sufficient to avoid overheating and, where necessary, in combination with heating systems to remove excessive moisture.

- 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.

- Light

  o 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.

   o   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-
       hour rhythm and include periods of darkness lasting at least six hours in total, with at
       least one uninterrupted period of darkness of at least four hours, excluding dimming
       periods.

- Inspection. All chickens kept on the holding must be inspected at least twice a day. Special
  attention should be paid to signs indicating a reduced level of animal welfare and/or animal
  health. Chickens that are seriously injured or show evident signs of health disorder, such as
  those having difficulties in walking, severe ascites or severe malformations, and are likely to
  suffer, shall receive appropriate treatment or be culled immediately. A veterinarian shall be
  contacted whenever necessary.

- Cleaning. Those parts of buildings, equipment or utensils which are in contact with the
  chickens shall be thoroughly cleaned and disinfected every time after final depopulation is
  carried out, before a new flock is introduced into the house. After the final depopulation of a
  house, all litter must be removed, and clean litter must be provided.

- Record keeping. The owner or keeper shall maintain a record for each house of a holding of:
  (a) the number of chickens introduced; (b) the useable area; (c) the hybrid or breed of the
  chickens, if known; (d) the causes, if known as well as the number of birds culled with cause;
  (e) the number of chickens remaining in the flock following the removal of chickens for sale
  or for slaughter.

- Those records shall be retained for a period of at least three years and shall be made available
  to the competent authority when carrying out an inspection or when otherwise requested.

- Surgical interventions. All surgical interventions carried out for reasons other than therapeutic
  or diagnostic purposes which result in damage to or the loss of a sensitive part of the body or
  the alteration of bone structure shall be prohibited.

- Beak trimming - may be authorised by Member States when other measures to prevent feather
  pecking and cannibalism are exhausted. In such cases, it shall be carried out only after
  consultation and on the advice of a veterinarian and shall be carried out by qualified staff on
  chickens that are less than 10 days old. In addition, Member States may authorise the
  castration of chickens. Castration shall only be carried out under veterinary supervision by
  personnel who have received a specific training.

The standard broiler house in Europe is window-less and actively ventilated. In some countries, the
introduction of windows to allow natural daylight is starting to be mandated by retailers – in the UK
for instance the retailer Morrissons requires that all of the farms producing chicken to be sold in their
stores will have windows and the potential for natural illumination, and in Sweden windows for
daylight are mandatory. The walls and the roof are generally insulated and the floor consists of
concrete although in France concrete floors are not generally used. A substantial part of the broilers in
Southern Europe are housed in open-sided ('Louisiana' type) houses.

Under conventional production systems in Europe the used litter is usually completely removed after
each batch, and the house is cleaned and disinfected. In general, poultry companies maintain
separation of housed birds from outside contact and establish biosecurity systems and use of
vaccination programmes to help protect housed birds from disease challenges.

All broilers are reared on litter (straw, wood shaving, peat, paper) and have free access to water. Some are fed *ad libitum,* and some are given 'meal time' feeding, having their daily ration split into timed feeding periods. In general, most commercial scale poultry feed is compounded in large feed mills and transported to the farm. Some farms will feed 'whole grains', not processed cereals, as part of the diet. Except for litter, feeders and drinkers, the house environment for most broilers is usually bare, however, some 'standard plus' systems are starting to require aspects of enrichment in their houses as part of their standards; these enrichments can include bales of straw, pecking blocks, reflective surfaces, perches, and fresh vegetable material to peck at and visual barriers.

A number of lighting regimes exist for indoor broiler production systems, but they are generally permutations on periodic light and dark periods. In the case where animals are in natural light, or have natural light plus some complementary light during the night, or are in artificial light only, the bird should be provided 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. These regimes must include periods of darkness lasting at least six hours in total, with at least one uninterrupted period of darkness of at least four hours, excluding dimming periods.

Light intensity during the photoperiod varies from 20 (minimum EU regulation) to over 1000 lux if natural light is provided in window houses, or houses with mesh or wire sides. In windowless houses the chicks can be started at intensities of about 20 lux or higher, and selection of the lighting system and intensity is made on the basis of the investment and operating costs rather than on routinely monitoring of physiological responses.

The poultry building's main role is to protect animals against climatic conditions. The major problems encountered are cold weather and hot weather, and high humidity. Broilers can be very sensitive to excess temperature if they become unable to lose and regulate heat effectively due to high ambient temperatures combined with high humidity. Certain ventilation and temperature conditions can lead to poor litter conditions which can be reflected in poor bird health, foot and hock skin conditions, poor bird hygiene and reduced quality of environment for both the birds and the stockman. Buildings differ according to climatic conditions. Very light buildings with windows, static infrared heaters and ventilation are common in southern countries, whereas in the north of Europe more sophisticated buildings are seen with good thermal insulation, dynamic ventilation, artificial light and uniform temperature inside the building. Rather than making specific technical prescriptions, the Broiler Directive 2007/43/EC places the onus on the producer to regulate ventilation and house temperature and humidity: ventilation shall be sufficient to avoid overheating and, where necessary, in combination with heating systems to remove excessive moisture.

Chicks need extra heat during the first weeks of life, and newly hatched chicks require ambient temperatures of 32 to 35°C. When whole room heating is provided the temperature above the litter should be adjusted to 35°C. Day-old chicks also require a high relative humidity (60-70%; (ROSS, 2009), which can be difficult to achieve at these high temperatures. The temperature is reduced gradually to 32°C at the end of the first week of age and to 26°C in the third week. The use of whole room heating varies in EU-countries, depending in the energy input costs and the climate.

Heat is usually provided by zonal brooder systems which are fuelled by gas or electricity, or by whole house heating systems based on combustion of gas or kerosene (or sometimes by wood or coal fired boilers, particularly in East European countries).

The final regulation of temperature is best carried out by direct observation of the chicks: crowding under the brooder shows that the temperature is too low while avoidance of the brooders indicates overheating. Zonal heating systems have the advantage of providing the young chick with a temperature gradient in which it can position itself according to its needs. Whole house brooding provides a more stable

environment but any dysfunction is potentially more damaging for the chicks' welfare and health. In addition, chicks are not able to choose their preferred temperature as there is no temperature gradient in the house.

Although by far the majority of broiler production is on litter material on the floor, there are moves to develop 'tiered' or 'patio' production systems in which multiple broad cage systems allow tiered production in climate controlled housing. This system is commercially available but not yet widely utilised for broiler production (Vencomatic, 2012).

Feeder space is regulated by many standards to permit adequate levels of feeder access under *ad libitum,* or meal fed conditions. With common pan feeding systems, many birds can access one pan. As an example, the Freedom Food standard specifies that there must be a minimum of 25mm of linear (single side) or 16mm of circular feeding space must be provided and accessible for each bird.

'Chain feeders' are increasingly considered as 'old technology' and some standards now prevent their use in newly build systems. It is recommended to provide feed on flat pans for recently introduced chicks during the first days. Feeding whole grain in addition to pellets is used where the price for farm grown cereals is low and commonly applied in countries such as Sweden and The Netherlands, and there is support for the belief that inclusion of whole grains stimulates utilisation of the crop and maximises overall uptake of nutrients in the diet (Biggs and Parsons, 2009; Svihus et al., 2010). Special equipment may be needed to meter the amount of whole grain in the pellet diet, or this may be included in the feed mill at source.

Standard broilers, which grow for 5 weeks usually receive 3 different diets: starter (1st week) containing about 210 g/kg crude protein (CP) and 12 - 13 MJ ME/kg; grower (2nd to 4th week) containing about 220 k/kg CP and 13 - 13.2 MJ ME/kg, and finisher (5th week) containing 190 g/kg CP and 13 - 13.32 MJ ME/kg. The grower diet can be provided from 2 weeks up to the end of the growing period if it does not contain coccidiostats (used to control but not eliminate the gut coccidian parasite *Eimeria*). The starter diet is usually fed as a crumb to increase uptake by the young chick and subsequently as a pellet. This enhances feed intake, and reduces food choice and feed wastes as compared with mash.

The majority of farms now use nipple and/or cup drinkers or only cup drinkers. As an example, the Freedom Food standard specifies 1 nipple drinker per 10 chickens, and one cup drinker per 28 chickens. Bell drinkers can be found in older farms and in smaller scale production. However, because the water trickles over the surface of the bell and can become contaminated with dust, they are now not recommended in most new build systems.

1.3.3.1. Methods of feed restrictions

See 1.3.3

1.3.3.2. Buildings

No new information.

1.3.4. Selection of meat type chicken

See 2.3. and 2.4. for updated information.

1.3.5. Consequences of genetic selection

See 2.3. and 2.4. and 3. for updated information.

1.4. Welfare problems in broilers

1.4.1. Mortality

See 2.1.1.for updated information.

1.4.2. Skeletal disorders

See 2.1.2. for updated information.

1.4.3. Muscle disorders

See 2.1.3.. for updated information

1.4.4. Contact dermatitis

See 2.1.4. for updated information

1.4.5. Ascites and sudden death syndrome

See 2.1.5. for updated information

1.4.6. Respiratory and mucous membrane problems

See 2.1.6. for updated information.

1.4.7. Stress indicators

1.4.7.1. The range of indicators

In addition to the indicators mentioned in the previous report (SCAHAW, 2000), the following stress indicators were described in literature.

Growth rate reduced with high stocking density, at least above 30 kg/m^2 (Bessei, 2006; Estevez, 2007). These results were confirmed by Guardia et al. (2011) who also found that an increase in stocking density was connected to a reduction in digestive microbes. However, it may be difficult to interpret what impact the reduction of microbes has on the health of the birds. A reduction of some microbes may be detrimental to health, whereas a reduction of others may be beneficial.

Heat stress has been found to decrease feed intake (Gonzalez-Esquerra and Leeson, 2006).

Buijs et al. (2009) found that leg strength decreased as stocking densities increased from 6 to 23 kg/m^2. Furthermore hock dermatitis increased as densities increased from 35 to 56 kg/m^2, and footpad dermatitis and fearfulness were found to increase as density was increased to 56 kg/m^2 (this stocking density exceeds that allowed in the EU Directive).

According to Butterworth (2004) easily detectable signs of health problems in broilers are

1. Withdrawal, where the bird withdraws from the rest of the flock and also becomes unreceptive to external stimuli.

2. Hunched posture, where the birds' head is held closely to the body, the tail is lowered and the eyes may be closed.

3. Dull feathers, where the plumage gives a dull impression and the feathers may look greasy. The bird does not preen to a normal extent.

1.4.7.2. Haematological responses

No new information.

1.4.7.3. Hormonal responses

Acute stress increases blood glucose and lactate levels, but for ethical as well as practical reasons blood samples might be unsuitable to use. Savenije (2004) invented and validated a device which may be used to collect subcutaneous fluid from underneath the wing and disturbing the birds to a minimum.

1.4.7.4. Enzyme responses.

No new information.

1.4.7.5. Behavioural responses

Buijs et al. (2011a) showed that broilers work hard to move to an area with decreased stocking density. The lower the stocking density was on the other side of a barrier the more individuals crossed the barrier. This is an indication that broilers prefer a lower stocking density than the commercially commonly used 42 kg/m^2.

Tonic immobility is a behaviour which is ultimately explained as an antipredatory behaviour where a bird, e.g. caught by a fox, relaxes completely and if the fox as a consequence eases its bite, the bird gets a chance to escape. Generally it is accepted that the duration of tonic immobility increase with increasing fear in the bird, hence tonic immobility duration is often used as a measurement of fear level. Sanotra et al. (2002) found that increased stocking density increased tonic immobility durations in broilers.

1.4.7.6. Genetic relationships

See 2.3. for updated information.

1.4.8. Thermal discomfort

See 2.1.7. for updated information

1.4.9. Behavioural restriction

The 2000 report mentioned that increased stocking density may restrict the possibility to perform litter directed behaviour and locomotion. Recent studies on this topic are conflicting, with some authors mentioning changes whereas others found no effect (see the update on 1.5.5.6.). However, studies are more equivocal on the increase of disturbances at higher density (Hall, 2001; Cornetto et al., 2002; Dawkins et al., 2004; Febrer et al., 2006; Buijs et al., 2010; Ventura et al., 2012) which were found to fragment preening and resting bouts (Hall, 2001; Buijs et al., 2010; Buijs et al., 2011b). Likewise, walking bouts were found to be shorter at higher density (Hall, 2001; Febrer et al., 2006; Buijs et al., 2010), with birds covering less distance per unit of time (Leone and Estevez, 2008ab), suggesting that it becomes increasingly hard to move around as density increases. Together with the findings of Bokkers et al. (2011) that broilers are compressed when kept at a stocking density of 16 birds/m^2 it can be suggested that more birds per unit area create a barrier effect that hampers dispersion of other birds throughout the space (Estevez, 2007; Collins, 2008). It is important to note that increased disturbance and decreased walking bout lengths were found even in large scale commercial studies in which

environmental influences overshadowed many other stocking density effects (Dawkins et al., 2004; Febrer et al., 2006).

Both restricted movement and disturbed rest may be expected to impact birds' physical development, with possible consequences for the occurrence of leg deformations which in turn predispose them to further behavioural restriction. In line with this, some treatments that increased exercise were found to decrease leg abnormalities (Prayitno et al., 1997; Reiter and Bessei, 1998; Stojcic and Bessei, 2009). However, the exact impact of exercise on leg health is not fully clear as Sherlock et al. (2010) found no relation between spontaneous activity and gait score or leg health on an individual level.

It has been suggested that the high body weight resulting from selection on growth performance may also cause behavioural restriction in broilers (Bokkers et al., 2007). Arnould and Faure (2003) showed that broilers spontaneously limited their physical activity, irrespective of the stocking density applied. In line with this, birds of slower growing strains are more active than those of fast growing strains (Bizeray et al., 2000; Nielsen et al., 2003b; Bosco et al., 2010). Alleviating part of the body weight experimentally by suspending fast growing broilers in a harness increased walking by 35% Rutten et al. (2002) suggesting that high body weight may be the cause rather than the effect. Experimental studies performed on slow and fast growing broilers (Bokkers and Koene, 2004) and on fast growing broilers divided into heavy and light birds compared with what they would normally weigh in commercial conditions (Bokkers et al., 2007), suggest that impaired physical ability is the dominant restrictive factor for walking in birds with a high body weight. In birds with a low body weight however the motivation to move is the guiding factor for locomotion. Fast growing strains spend more time eating (Nielsen et al., 2010) and have an increased daily feed intake (Howie et al., 2009) than slow growing strains. Characteristics of eating behaviour of fast growing broilers indicated a disturbed satiety mechanism (Bokkers and Koene, 2003b), although other studies did not find differences in the structure of feeding behaviour of genetic lines that were more strongly selected for rapid growth, suggesting that selection has not changed the normal controls of feeding behaviour (Howie et al., 2009; Howie et al., 2011).

There is some evidence that both activity and rest are limited by the barrenness of standard broiler housing, and can thus be increased by enriching the environment. Scattering feed pellets in the litter was found to increase walking and foraging (Jordan et al., 2011), whilst sand increased foraging with a minimal effect on walking (Arnould et al., 2004). Straw bales were found to increase walking and running (Kells et al., 2001). However, Bizeray et al. (2002a) found that scattering wheat in the litter, bright moving spots of light or wooden barriers did not influence walking or foraging, although birds in the barrier treatment spent some time perching instead of lying. Ventura et al. (2012) likewise showed a substantial increase in perching with the application of wooden barriers, in addition to a reduction in aggression and disturbances. Providing vertical panels may be another way to reduce disturbances (Cornetto et al., 2002) and thus increase rest (Cornetto and Estevez, 2001b). Providing bright red light was found to increase walking, feeding and stretching, particularly when applied early in the growth period (Prayitno et al., 1997). Greater light intensity increased activity in the light phase whilst decreasing it in the dark phase (Alvino et al., 2009a; Blatchford et al., 2009). It also led to longer uninterrupted resting bouts in the dark phase due to increased behavioural synchronization (Alvino et al., 2009b) and could thus potentially improve activity as well as increase the possibility for undisturbed rest.

1.4.9.1. Conclusions

1. High stocking densities disturb locomotor behaviour and rest, both of which have an influence on leg health in broilers although the nature of this impact is not clear.

2. Selection for increased growth impedes the activity level of broilers.

3. Enrichment strategies may alleviate behavioural restriction if broilers by increasing locomotion and preventing disturbance of rest.

1.5. Environmental factors linked to welfare problems

In the updated text, parts of the original text were included.

1.5.1. Air quality

The environment in the poultry house is a combination of physical and biological factors which interact as a complex dynamic system of interactions between birds, husbandry system, light, temperature and the aerial environment (Sainsbury, 2000). Aerial environment (air quality) including temperature, humidity, dust level and concentrations of carbon dioxide, carbon monoxide and ammonia should be controlled and kept within limits where the welfare of the birds is not negatively affected (DEFRA, 2002). The EU Broiler Directive (Commission, 2007) advises 20 ppm for ammonia, 3,000 ppm for carbon dioxide and 70% for relative humidity as upper limits.

Pollutants include organic and inorganic dust, pathogens and other micro-organisms as well as gases such as ammonia, nitrous oxide, carbon dioxide, hydrogen sulphide and methane or other compounds like endotoxins and even residues of antibiotics (Kristensen and Wathes, 2000; Saleh, 2006). Gases, dust and micro-organisms form bio-aerosols and there is strong epidemiological evidence that bio-aerosols cause directly infectious and allergic diseases in farm workers and animals. Chronic exposure to some types of aerial pollutants may exacerbate multi-factorial environmental diseases (Saleh, 2006). In addition, air contaminants may depress the growth of the birds (Wathes, 1998).

The main sources of aerial pollutants are the feed, the litter and the chickens themselves. They are indirectly or directly influenced by season, diseases, nutrition and the management (Wathes, 2004). It is remarkable that broiler chickens tolerate the high burden of aerial pollutants, and yet there are reasons for concerns that their welfare may be compromised by chronic exposure (Wathes, 2004). Wathes (2004) suggested that the current guidelines for air quality should be revised and lower limits considered.

1.5.1.1. Humidity

Humidity depends mainly on factors within the building but also on outside humidity. Examples of important factors in the building are stocking density, live weight of the birds, ventilation rate, indoor temperature, number, type and management of drinkers, water consumption and water spillage. Temperature and relative humidity influence the thermal comfort of the birds (SCAHAW, 2000). A relative humidity of 60-70% in the house is necessary in the first three days (ROSS, 2009). Relative humidity above 70% can occasionally be reached with high stocking densities in winter time when the ventilation rate may be reduced to retain heat and save energy (Meluzzi and Sirri, 2009; ROSS, 2009). At later ages high relative humidity causes wet litter and its associated problems. During summer, broilers may often experience discomfort due to the combined effect of high humidity and high temperature (Meluzzi and Sirri, 2009). Relative humidity below 50% leads to an increase in dust and micro-organisms, which increase the susceptibility to respiratory diseases (Robins and Phillips, 2011). This situation is not very common and normally occurs only in the first or second week of life.

Adequate ventilation rates provide the most effective method of controlling temperature within the house and also allows for control of relative humidity (Jones et al., 2005) and can play a key role in alleviating the negative effects of high stocking density and of wet litter. Litter moisture is positively correlated with the incidence of foot pad dermatitis (Shepherd and Fairchild, 2010), one of the most important welfare indicators (Meluzzi and Sirri, 2009).

It has been found that the percentage of birds dying over the whole growth period was positively correlated with humidity and temperature in weeks 3-5 (Dawkins et al., 2004). From this large field study it was concluded that housing conditions (litter quality, temperature and humidity) were more important for animal welfare than stocking density in itself.

1.5.1.2. Gases and air contaminations

The most important role of ventilation is to remove carbon dioxide and water from the air of the house. Adequate oxygen supply is essential for the early stages of cardiovascular system development. Low oxygen supply and low ambient temperature increase the risk of ascites. The ventilation system should have a fan capacity of at least 12.5% of the air volume in the house to reduce the risk of hazardous levels of gases (Wilson, 2008).

Carbon Dioxide

Carbon dioxide (CO_2) is a non-reactive gas, which is removed only by ventilation contrary to a reactive gas like ammonia which may interact chemically, for example, by absorption on wet building surfaces or dust particles. CO_2 is a metabolic by-product of both broiler chickens and litter processes (Wathes, 2004).

The minimum ventilation rate is calculated on the basis of CO_2 production by the chickens and the litter.

Ammonia

Ammonia is a colourless gas with a pungent odour, produced in the litter by microbial decomposition of nitrogen-containing substances (Al-Homidan, 2003). Ammonia can irritate eyes, throat and mucous membranes in humans and farm animals (Aziz and Barnes, 2010). Its excessive concentration in the air may cause blindness, skin burns and a decreased weight gain in broilers (COBB, 2008). The smell of ammonia can be detected by humans at concentrations of less than 10 ppm. Ammonia levels of 10 ppm or more in the broiler house can damage the lung surface and increase the susceptibility for respiratory diseases (Aziz and Barnes, 2010). Damage to the mucous membranes of the respiratory system increases the susceptibility of birds to bacterial respiratory infection, especially *E. coli* infection (Aziz and Barnes, 2010). High levels of ammonia have a negative impact on overall liveability, weight gain, feed conversion, condemnation rate at processing and the immune system of the birds (Aziz and Barnes, 2010) (Ritz et al., 2004). Ammonia concentrations at 25 and 50 ppm induced eye lesions after 7 days after initial exposure (Olanrewaju et al., 2008). The growth rate of broilers is reduced at ammonia levels higher than 50 ppm (ROSS, 2009). According to Aziz and Barnes (2010) ammonia concentrations of 50 and 75 ppm reduced body weight by 17% and 20% respectively at 7 weeks of age as compared to broilers kept in an environment with ammonia concentration near 0 ppm.

In broiler houses, the most important factors influencing ammonia production are air temperature, ventilation rate, humidity, feed composition, age of the litter, litter pH, moisture content, litter type, stocking density and age of birds (Al-Homidan, 2003).

In this context, it should also be borne in mind that many countries have regulations for human exposure, which set upper limits for the acceptable ammonia concentration in working environments. For example, in the UK the limit is 25 ppm (Charles, 1980 according to Bessei, personal communication) and in Sweden and Germany (DFG 1999, according to Bessei, personal communication), it is 25 ppm and 20 ppm, respectively, for an 8 h working day. Sweden also has a limit of 50 ppm for a maximum of 5 min exposure.

Seasonal variation in ammonia concentrations can occur as a result of reduced ventilation rate in the winter months in order to save energy. Kristensen and Wathes (2000) reviewed the effect of ammonia exposure on various aspects of poultry welfare. The behavioural responses of poultry to ammonia suggest that the birds can detect and avoid ammonia concentrations at or below 25 ppm. The review suggests that ammonia exposure adversely affects the physiology, production and behaviour of poultry and hence compromise the birds' welfare.

When broiler chickens were given a choice of atmospheres with different concentrations of ammonia or fresh air without ammonia (control group), fresh air was significantly preferred. Both the duration and frequency of visits to a chamber declined with increasing ammonia concentration (Jones, 2002). Another study suggested that 5 ppm should be the maximum ammonia level for broilers (Owada, 2007).

In a field study it was shown that ammonia and litter moisture were related to bird health and positively correlated with more dirty foot pads, more legs scored as angle-out and fewer birds with unblemished hock (Dawkins et al., 2004).

The effect of different concentrations of atmospheric ammonia (0, 13, 26, 52 ppm) on growth performance and immunological response of broilers from 0-3 weeks of age was studied by Wang et al. (2010). Growth was significantly reduced at the highest concentration of ammonia as compared to the control group. Relative lymphoid organ weights decreased with increasing ammonia concentrations, and antibody titre in response to Newcastle Disease Virus was significantly reduced at the highest ammonia concentration (Wang et al., 2010).

Considering the behavioural and physiological responses of broilers to increased levels of ammonia (DEFRA, 2002) recommended a maximum ammonia concentration of 20 ppm.

Other gases

Detrimental carbon monoxide (CO) concentrations only occur when heating systems are used where the fuel is burned inside the brooder room. When the room is not sufficiently preheated the production is run at full capacity and ventilation rate is reduced. Preheating of the broiler houses for at least 24 hours before the chicks arrive is essential to avoid damages through elevated CO and CO_2 concentrations. According to the breeder manuals (ROSS, 2009) 100 ppm CO reduces oxygen binding and causes death.

In a study in Brazil carbon monoxide concentration in the brooding phase was above the 10 ppm maximum recommended value, and it was higher during the cold season in a tunnel type broiler house (30 ppm) as compared to a conventional house (18 ppm). For nitrous oxide and methane only traces were found while CO_2 concentrations evaluated during the daytime were below the limit of 20 ppm (Nääs, 2007). Bocquier et al. (1999) in SCAHAW (2000) found that CO ranged up to 50 ppm, depending on the type of ventilation and heating system. The authors considered that under good management conditions CO levels between 14 to 35 ppm can be tolerated. It is important to note that CH_4, H_2S, and N_2O play a role as environmental pollutants but do not harm the birds under commercial conditions (Bessei, personal communication) and the risk for hazardous levels can be kept at a minimum by using a ventilation rate of a minimum of 0.8 m^3/hour/kg liveweight (Le Menec, 1987).

The harmful effect of high levels of ammonia in poultry houses can be increased by the simultaneous occurrence of other stressors, such as heat and humidity (SCAHAW, 2000).

Dust

Dust in the atmosphere of broiler houses can have deleterious effects on broiler health and performance. High levels of inspirable dust can cause respiratory problems in broilers (Al-Homidan, 2003).

Dust in broiler houses arises mainly from feathers and feather follicles, skin scales, feed and litter. Dust is made up of fractions of differently sized particles. According to Gastaldo (1992), the largest particles (>5 μm; the inspirable fraction) are largely stopped in the nostrils, but can produce irritation and infections in the nose and throat. Of the smaller particles (the respirable fraction), the largest can reach the trachea, and cause irritation, mucous membrane damage and reduced feed intake. The smallest particles (inhalable dust) can enter all the way down to the lungs. They can carry bacteria, viruses and other substances such as endotoxins and antibiotic residues to the deeper lung tissue, thereby causing infections, as well as lowering respiratory capacity and oxygen uptake. Endotoxins in particular can cause significant human and animal health problems (Radon, 2001; Seedorf, 2002; Radon, 2003; Wang et al., 2003).

Inspirable dust concentrations of up to 10 mg/m³ were found in the air of broiler houses at the end of the fourth week of fattening which is 2.5 times higher than the allowed concentration for workers in Germany (4 mg/m³). The maximum concentration for respirable dust (1.5 mg/m³) was rarely exceeded, and concentrations between 0.4 and 1.2 mg/m³ were regularly observed. The amounts of dust deposit range between 1.2 and about 7.0 g/m²/24 h in the broiler houses and demonstrate a strong seasonal influence with highest values in winter (Saleh, 2006).

A comparison of two types of broiler houses (conventional and tunnel type) showed that the total dust concentration in both houses were not excessive, but above maximum concentration recommended for humans regarding the inhalable dust (Nääs, 2007). Application of oil to the litter appear to be a simple, inexpensive method to reduce dust concentrations and odour in broiler houses (Uhllman, 2004; Aarnink et al., 2011). Spraying rapeseed oil significantly reduced dust concentrations and emissions from broiler houses. However, high levels of oil has adverse effects on foot pad quality and the maximum rate should be 16 ml oil/m²/d (Aarnink et al., 2011).

Dust in broiler houses can be minimised through the use of proper ventilation and by keeping relative humidity at recommended levels.

1.5.1.3. Conclusions

1. Air quality in a broiler house is determined by a complex interaction between many factors including ventilation, stocking rate, litter quality, age and health status of the birds. The EU Broiler Directive (Commission, 2007) advises 20 ppm for ammonia, 3,000 ppm for carbon dioxide and 70% for humidity as upper limits.

2. Air humidity largely dependent on appropriate operation of the ventilation and drinker system but is also dependent from outside humidity. When levels increase to more than 70% under high temperature, serious welfare problems occur, and animals may die. Relative humidity below 50% leads to an increase in airborne particulate matter and increasing susceptibility to respiratory diseases.

3. Levels of CO_2 of 1% do not, by itself, cause any harm for animals. However, an increase in CO_2 levels is usually accompanied by increased levels of other detrimental air pollutants such as ammonia, dust and micro-organisms. Therefore CO_2 is used as an air quality indicator.

4. High concentrations of ammonia are regularly observed in commercial broiler houses. The

harmful effects result from a combination of high concentration and exposure time. Concentrations over 10 ppm increase the susceptibility for respiratory diseases.

5. N2O and CH4 do not occur in broiler houses in concentrations which may influence health or welfare of animals. Other gases, such as CO and H2S, are potential risk factors for broiler welfare, but there are little data available on commonly occurring concentrations or on risk levels.

6. Dust is a potentially harmful air contaminant, mainly in combination with ammonia and other gases and may directly affect the respiratory tracts of the broilers, as well as act in the transmission of bacterial and viral infections. Dust levels can be kept to a minimum by appropriate ventilation and by maintaining recommended humidity levels

1.5.2. Litter quality

The importance of good litter quality for rearing of broilers is well recognised. Litter quality will affect the environment of the birds by influencing dust levels, air humidity and ammonia levels, factors that influence the birds' risk of developing respiratory problems. Litter quality also has a direct influence on the skin condition of the birds. Wet litter is a major risk factor for contact dermatitis (see 2.1.4. for the relation between litter quality and contact dermatitis) (Shepherd and Fairchild, 2010). In a 2001 UK survey, wet litter was reported by 75% of the farmers (Hermans et al., 2006). Litter of good quality enables the birds to perform litter-directed behaviours such as scratching and dust bathing.

Moisture levels may be affected by litter material, amount and texture of litter, the type of drinkers and water consumption (including water spillage), air temperature and season, stocking density, bird age, diseases (diarrhoea), and diet composition as this affects the amount, water contents and viscosity of faeces.

Baeza et al. (2012) showed that with increasing age of broilers the moisture and ammonium content of litter increased rapidly, as well as occurrence and severity of contact dermatitis. It has been shown that the incidence of foot pad dermatitis (FPD) was significantly increased when the litter moisture was increased by wetting at 14 days of age, but not when the broilers were older than 56 days of age (Cengiz et al., 2011). The severity of FPD was reduced with improvements in bedding quality. Moreover, particle size of the litter had a direct effect on the occurrence of FPD. FPD may occur early in the growing period when litter moisture is low (Hashimoto et al., 2011; Oliviere et al., 2011). Subsequent improvements in litter quality could reverse the severity of lesions in market-age broilers (Cengiz et al., 2011) although in practice it would be very difficult to improve litter condition in such a way that lesions will heal (De Jong, personal communication). Also, prevention of FPD is a better strategy than cure in welfare terms.

A wide variety of litter types have been considered for broilers. For examples, alternative litter materials (Pelletinos (chopped straw pressed into pellets at high temperature), spelt glumes, HygieneWood-Shavings (pine heartwood) compared to standard litter materials for broilers (chopped straw, wood shavings) were investigated regarding their influence on foot pad dermatitis and animal performance. Groups kept on Pelletinos showed the best foot pads and the highest body weights whereas chopped straw seems to be the least suitable variant (Berk, 2009). In a study comparing four litter types (pine wood shavings, dried hemp waste, and chopped wheat straw either turned regularly and refreshed or left untouched) on indices of leg weakness it was shown that birds reared on wheat straw had poorer walking ability and more FPD than birds reared on wood shavings, and birds reared on hemp waste were intermediate between them. There was no effect of litter substrate on tibial dyschondroplasia or tibial curvature. Turning the straw litter regularly and adding fresh supplies when necessary did not significantly improve indices of leg weakness (Su et al., 2000). Another study

compared sludge from paper recycling with wood shavings as bedding material. There were no major differences in welfare indices (tonic immobility, gait score, contact dermatitis, tibial dyschondroplasia) of the birds on either substrate, only the incidence of hock burn was higher on paper sludge as compared to wood shavings (Villagra et al., 2011). Another study compared eight bedding types (pine shavings, pine bark, chipped pine wood, mortar sand, ground hardwood pellets, chopped straw, ground door filler (a wood fiber-based material used in insulating metal doors), and cotton-gin trash). The incidence of foot pad dermatitis paralleled high litter moisture and caking scores, with chipped pine wood, chopped straw, cotton-gin trash, and pine shavings showing the highest severity scores and mortar sand and ground door filler showing the lowest (Bilgili et al., 2009). In a study on commercial farms in Brazil, four different types of litter material, Brachiaria grass, corncob, sawdust and rice shell, were used. Broilers reared on Brachiaria grass litter showed the highest incidence of foot-pad dermatitis. Corncob litter also increased FPD levels. Broilers raised on rice shell litter showed good results in terms of the incidence of contact FPD. Sawdust litter was most effective in lowering cellulitis, arthirits and FPD (Xavier et al., 2010). A study under semi-commercial conditions showed that the use of peat as litter material significantly reduced FPD as compared to wood shavings or chopped straw as litter (Zoons, personal communication).

In a dust bathing choice test experiment using four different bedding types (pine wood shavings, rice hulls, construction grade sand, and a recycled paper animal bedding product) it was shown that broiler chickens spent more time on sand than on the other substrates, and that sand stimulated dust bathing behaviour (Shields et al., 2004). In another experiment the behaviour of broilers on sand and wood shavings was observed. The results indicated that when given a choice, broilers increasingly performed many of their behaviours on sand. However, if they were given only one substrate (sand or wood shavings) there were no differences in frequency of behaviours between the substrate types (Shields et al., 2005).

It has been suggested that visual inspection together with the measurement of litter temperature and pH using mobile measuring devices are to be a useful and practical procedures in order to assess litter quality in broiler houses (Spindler, 2009). The Welfare Quality® assessment protocol for broilers describes a scoring system for litter quality, ranging from a score 0 (completely dry and flaky, moves easily with foot) to 4 (sticks to boots once the cap or compacted crust is broken) (Welfare Quality®, 2009). Regular assessment of litter quality and inspection of feet in a sample of birds from the first week of age onwards appears to be the key strategy in controlling the onset of contact dermatitis (Nielsen, personal communication).

1.5.2.1. Conclusions

1. Maintaining a good litter quality is essential for broiler health and welfare. Failure to do so may result in respiratory problems and contact dermatitis in the birds.

2. Litter quality is partially related to the type of substrate, nutrition, management of ventilation and water supply (prevention of spillage). The risk of contact dermatitis can be reduced by the choice and appropriate management of litter material and drinker systems.

3. Regular visual inspection of litter (e.g. during daily flock inspection) and avoidance of high moisture content and inspection of feet conditions from the first week of age onwards appears to be the key strategy to avoid foot pad dermatitis and other health problems.

4. The Welfare Quality® assessment protocol includes a system scoring litter quality in commercial flocks.

1.5.3. Temperature

Air temperature (and humidity) is affected by stocking density, season and ventilation system (Alchalabi, 2002). Recommended (whole house) ambient temperatures for broilers decline progressively from 30°C at the first day of life down to 20°C at 27 days and thereafter (ROSS, 2009). It should be noted that the temperature requirement for day-old broiler chicks is 35°C at bird level. It is important to observe the behaviour of the chicks to ensure that they experience an adequate temperature. Huddling indicates that the environmental temperature is too low, whereas panting and/or holding the wings away from the body indicate that the environmental temperature is too high. The Welfare Quality® assessment protocol for broilers measures the proportion of birds showing panting or huddling as indicator of thermal discomfort (Welfare Quality®, 2009).

Fast growing broilers may have problems in dissipating heat under commercial conditions. As litter temperature rises with increasing stocking density, passive heat dissipation is impaired (Reiter and Bessei, 2000). Broilers first respond to heat challenge through reduced walking, standing and preening (Lolli et al., 2010). Panting as an efficient physiological mechanism of active heat dissipation is common in broilers even under stocking densities lower than 20 kg/m² (Lolli et al., 2010). In a study comparing different stocking densities, it was shown that panting in six week old broilers increased when stocking density was increased from 28 kg/m^2 to 34 and 40 kg/m^2, indicating that thermal discomfort becomes a problem at higher stocking densities at the end of the growing period (McLean et al., 2002). Baeza et al. (2012) showed that panting behaviour increased with age of the broilers.

In an experiment studying the effect of different ambient temperatures on growth, behaviour and feed intake of a fast and slow growing strain of broilers, it was shown that fast growing broilers use behavioural changes when trying to adapt to warm environments, whereas slow growing broilers use metabolic changes to adapt to cooler ambient temperatures. Considering behavioural and physiological changes and growth as welfare indicators, the optimum temperature for fast growing broilers at the end of the growing period might be lower than the present recommended standard (Nielsen, in press).

1.5.3.1. Conclusions

1. The risk of heat stress in broilers increases with age and with stocking density as heat production increases and as space between birds (and hence their ability to lose heat) decreases.

2. There are indications that fast and slow growing strains differ in the way they cope with warm environments.

3. The proportion of broilers showing panting or huddling behaviour can be used as indicator of thermal comfort of the birds.

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1.5.4. Light

Light is an important management tool to regulate broiler production and welfare by modulating various behavioural and physiological pathways. Artificial lighting for broilers consists of four aspects: photoperiod, light intensity, source and wavelength. These can each have significant effects on broiler production and welfare (Prescott et al., 2003), and may also interact with one another.

1.5.4.1. Photoperiod

Light management is widely used to improve production efficiency. The Ross breeder's guidelines (ROSS, 2009) recommend that 23 hours of light with 30-40 lux intensity should be provided during

the first seven days to help the chicks adapt to the new environment and encourage feed and water intake. The EU Broiler Directive (Commission, 2007) states that a dark period of 6 hours in total with at least a four hour period of uninterrupted darkness should be provided per 24 hours from 7 days of age onwards until three days before slaughter.

Under experimental conditions, Malleau et al. (2007) found that broiler chicks given a simulated natural brooding cycle of 40 min L: 40 min D within a 19L:5D programme during the entire first two weeks were able to consume enough feed to attain the same body weight as those reared with 19 hours of light per day, despite being given less than 10 hours of light in a 24-hour cycle. The chicks given the simulated brooding cycle were also able to rest more because the photo schedule facilitated periods of synchronised high activity when the lights were on and of low activity when the lights were off. Longer periods of darkness (e.g. 16L:8D) during early rearing have been shown to reduce early growth as compared to continuous lighting, although compensatory growth does occur by 35 days of age (Bayram and Ozkan, 2010).

A number of different types of lighting schedules are used commercially after the first few days of age. These include restricted lighting (one continuous period of light and one continuous period of dark each 24 hour period, e.g. 16L:8D), intermittent light (short periods of light and dark provided multiple times during each 24 hour period, e.g. a cycle of 1L:3D repeated 6 times, although in the EU a continuous dark period of 4 h should be provided), a combination of restricted and intermittent, and increasing and/or decreasing photoperiods. There has been considerable research on the effects of photoperiod on productivity and health (see review in (Olanrewaju, 2006)).

In general, birds provided with sufficient dark periods have fewer health related problems, including sudden death syndrome, spiking mortality, tibial dyschondroplasia, eye enlargement, and leg problems than broilers kept in continuous or near continuous light (Apeldoorn et al., 1999; Moore, 2000; Sanotra et al., 2002; Lewis and Gous, 2009). It has been shown that normal ocular development in the chick requires a minimum of 4 h darkness per day, provided at the same time of the day without interruption (Li et al., 2000). Decreased photoperiods are also reported to decrease susceptibility to metabolic diseases such as ascites associated with pulmonary hypertension syndrome, sudden death syndrome, tibial dyschondroplasia and other skeletal disorders, and decreased mortality (Classen and Riddell, 1989; Classen et al., 1991; Renden et al., 1991; Petek et al., 2005; Lewis et al., 2009; Schwean-Lardner et al., in press-a). Intermittent lighting programs are generally found to result in superior productivity compared to constant lighting programs (Classen, 2004; Rahimi, 2005). Intermittent lighting programs are designed to slow early growth in order to reduce metabolic and skeletal disorders (Olanrewaju, 2006).

There has been some recent research evaluating the effects of restricted lighting programs on aspects of broiler welfare and production. Lewis et al. (2009) compared continuous photoperiods of varying lengths (providing from 2-22 hours of light per day), and found no effects of photoperiod length on feed intake or growth up to 35 days of age as long as the dark period did not exceed 18 hours. Dark periods longer than 12 hours, however, decreased feed conversion efficiency. Schwean-Lardner et al. (Schwean-Lardner et al., In press-b) evaluated continuous dark periods of 1, 4, 7 or 10 hours, and found that 49-day body weights were lower in the broilers given more than 7 hours of darkness, while feed consumption was greatest with 4 hours of darkness. Bayram and Ozkan (2010) compared continuous lighting with a 16L:8L programme, and found no differences in feed conversion or body weight at 6 weeks of age.

Only a few studies have examined the behaviour of broilers under different photoperiods. Broilers on a16L:8D lighting schedule at 20 lux showed more comfort and active behaviours and rested less during the light phase of the photoperiod than did broilers given 24 hours of light. The authors suggest that the 16L:8D birds rested mostly during the dark phase, although this was not measured. Birds

given continuous light were also more fearful (as measured by the tonic immobility test) and less social in a social reinstatement test (Bayram and Ozkan, 2010). Schwean-Lardner et al. (in press-a) examined the behavioural time budgets of broilers kept under restricted photoperiods that provided from 14 to 23 hours of light daily. Active and comfort behaviours were reduced, and avoidance behaviour in the presence of an observer was greater, in birds given near-continuous light, although there were no photoperiod effects on tonic immobility.

There is little information on the behavioural responses of broilers to intermittent-type lighting programs. Duve et al. (2011) reported that broilers had similar feeding activity regardless of whether the 8-hour dark period was provided continuously or in two 4-hour blocks. Ohtani et al. (1998) compared feeding and standing behaviour under continuous light and various intermittent programs, and found that intermittent lighting had a stimulatory effect on behaviour, but only during the early stages of rearing.

Shorter days improved welfare through fewer skeletal problems (Classen et al., 1991), less mortality (Brickett et al., 2007b; Schwean-Lardner, 2010), improved walking (Sanotra et al., 2002; Brickett et al., 2007a; Knowles et al., 2008), and increased the time spent on several behaviours (eating, drinking, pecking, scratching, standing, vertical wing-shaking) and reduced fearfulness (Sanotra et al., 2002). Lewis and Gous (2009) pointed out that a minimum period of darkness is necessary to maintain chicken eye growth within the normal range. Very short photoperiods as well as ultra-long photoperiods and continuous illumination have negative effect on ocular development with potential welfare implications.

1.5.4.2. Light intensity

In commercial broiler production a light intensity of 30-40 lux from 0-7 days of age and 5-10 lux thereafter has been recommended to improve feeding activity and growth (ROSS, 2009). Within the European Union, lighting requirements are based on Council Directive 2007/43/EC, which states that a light intensity of at least 20 lux during the light phase must be provided at all ages. In most experimental studies brighter light is provided during the first week of life, as recommended to stimulate feeding, and there are a limited number of studies specifically evaluating appropriate light intensities for chicks. Extremely dim lighting (0.2 lux) causes temporary reductions in growth as compared to 20 lux lighting (Olanrewaju et al., 2008), but weight gain is similar in chicks given 10 or 20 lux of light during the first week (Downs et al., 2006).

Most recent studies have found that broilers can be reared in light intensities ranging from as low as 1 lux to as high as 200 lux with no adverse effects on production, gait, mortality, or physiological or immune measures (Kristensen et al., 2006; Olanrewaju et al., 2008; Blatchford et al., 2009; Deep et al., 2010a; Olanrewaju et al., 2010; Deep et al., 2012); but see (Quentin et al., 2005; Lien et al., 2008) showing that market-age body weight is higher in dim lighting), although footpad and hock condition are sometimes worsened by either very dim or very bright lighting (Blatchford et al., 2009; Deep et al., 2010a). Light intensities of 10 lux or more may negatively affect some processing characteristics, particularly by decreasing carcass, thigh, wing, and/or drum yield (Downs et al., 2006; Lien et al., 2008; Deep et al., 2010a). Light intensity also has significant effects on eye health. As with continuous or near-continuous lighting, many studies have shown that broilers reared in dim (5 lux or less) light have larger and/or heavier eyes (see (Blatchford et al., 2009; Deep et al., 2010a)), which could indicate impaired vision.

When given a choice, broilers prefer more brightly lit areas when they are active and more dimly lit areas when they are inactive (Newberry, 1995; Davis et al., 1999). One study found that alternating the light intensity every 2-4 hours between 5 and 100 lux increased broiler activity (Kristensen et al., 2006), although this was not seen in a subsequent study where the light was alternated between 10 and 200 lux four times per day (Sherlock et al., 2010). In general, though, light intensity appears to have

little effect on behaviour. Broilers reared in brighter (50, 100, or 200 lux) light are not more active overall than those reared in dimmer (5 lux) light (Kristensen et al., 2006; Blatchford et al., 2009), although the birds reared in dimmer light may show reduced activity during the lights-on period and a less distinct diurnal pattern of activity (Blatchford et al., 2009). Behavioural time budgets are also relatively resilient under different lighting intensities, although preening (Alvino et al., 2009a; Deep et al., 2010b) and foraging (Alvino et al., 2009a) may be reduced, and resting increased (Deep et al., 2010b), in low (1 or 5 lux) light intensities.

However, the main effect of light intensity appears again to be related to the diurnal patterning of behaviour. Broilers raised with little intensity contrast between the lights-on and lights-off period show a more even distribution of behaviours over the photoperiod than those raised with a higher contrast. One consequence of this is that the behaviours in the flock are less synchronized (Alvino et al., 2009a). This can affect resting, because active birds may disturb the sleep of resting birds. Alvino et al. (2009a) found that broilers raised with higher illumination (200 lux) had fewer, longer, and less interrupted bouts of resting during the dark phase than those reared with lower (50 or 5 lux) illumination, although the average length of resting bouts was very short (about 3 minutes) even in the high illumination group. Both the contrast between the light and dark phase illumination, and the absolute intensity level during the dark phase, may have important influences on behaviour patterns. Broilers given 1 lux of light during the dark phase spend 10-20 percent of their time performing active behaviours (eating, drinking, walking, preening or foraging; (Alvino et al., 2009a)), while those kept in complete darkness are active for only about 2% of the dark phase (Deep et al., 2012).

1.5.4.3. Light source and wavelength

According to ROSS (2009) growth in broilers is affected by light spectra. Broiler growth rate appears to be better in birds exposed to wavelengths of 415-560 nm (violet to green) than in those exposed to over 635 nm (red) or broad spectrum (white) light at the same light intensity. However, there is little scientific information on the effect of light source and wavelength on broiler welfare. Broilers reared under blue or green light gain significantly more weight than those reared under red or white light (Rozenboim et al., 2004).

1.5.4.4. Interactions

Although the various aspects of lighting programs are often assessed and discussed independently, all of them potentially interact in ways that can affect welfare. For example, light source can affect how the broilers perceive the light intensity. In addition, photoperiod can be thought of as comprising a change in light intensity over a period of time. Few studies have evaluated the interactions of aspects of light. A comparison of near continuous (23L:1D) and 16L:8 dark photoperiods at either 1 or 10 lux (Lien et al., 2007) showed that body weight at 49 days of age was highest in dim illumination regardless of photoperiod, although body weight at earlier ages was decreased by providing 8 hours of darkness. There were no effects of treatment on heterophil to lymphocyte ratios, feed conversion, or mortality, but breast meat yield was reduced by both dim lighting and the 16L:8D photoperiod. Downs et al. (2006) evaluated constant (20 lux) versus decreasing (from 10 lux to 1 lux) light intensity under either a near-constant (23L:1D) or decreasing/increasing photoperiod, and found that low intensity lighting initially stimulated growth but that compensatory growth occurred under the other conditions and by 56 days of age; there were no treatment effects on mortality. Blatchford et al. (submitted, Mench, personal communication) evaluated the health and behaviour of broilers kept under either 1 or 200 lux (0.5 lux darkness), with photoperiods of either 20L:4D or 16L:8D. The only effects seen were that broilers reared in dim lighting had larger eyes and lower behavioural rhythms, regardless of photoperiod length.

1.5.4.5. Conclusions

1. Lighting programmes that provide shorter photoperiods during the first week of age would appear to confer benefits for broiler welfare without necessarily compromising performance.

2. Continuous or near-continuous lighting has negative effects on broiler behaviour and health as well as very short photoperiods; however, it is difficult to determine an optimal photoperiod or photoperiods for welfare because of the wide variety of photo schedules that have been studied. Several studies have shown that a continuous period of darkness of four hours as indicated in the EU Broiler directive should not negatively affect performance as compared to shorter continuous periods of darkness. However, intermittent lighting schedules that provide darkness in blocks of less than 4 continuous hours have also been shown to be beneficial in reducing metabolic and skeletal disorders. The age-dependent responses for feed intake and body weight gain mean that one photoperiod may not be appropriate for all slaughter ages.

3. Dim illumination (less than 10 lux) during the lights-on period also has negative effects on broiler behaviour and leg and eye health. However, recent studies suggest that an illumination level of 10 lux is sufficient to promote normal behavioural rhythms and good skeletal and eye health. Levels above 10 lux may be associated with some decreases in yield.

4. Behaviour patterns of broilers are influenced by the contrast in intensity between the light and dark period, as well as by the absolute intensity level in the dark period. The effect of contrast in intensity on broiler welfare needs further research.

5. Since the four aspects of light interact with one another they cannot be considered independently. Thus, regulations or codes designed to standardise light levels need to take account of the fact that broilers may perceive the luminance from different light sources differently. In addition, it is important to consider not only daytime illumination levels, but night time illumination levels and the intensity contrast between the two.

1.5.5. Stocking density

Recent studies have not been able to provide a clear critical density from which point on welfare is decreased. Instead, this critical density is found to vary not only between different welfare indicators, but also between different studies focusing on the same indicator over a similar range of densities.

Such contradictions may in part be explained by differences in the environmental conditions under which the studies were performed, since stocking density effects can sometimes be overshadowed by the negative effects of divergence from recommended humidity and temperature (at least within the 30-46 kg/m^2 density range: (Jones et al., 2005)). On the other hand, when stocking density is increased, this may lead to increased humidity and heat production near the end of rearing (Jones et al., 2005; Bessei, 2006). In nearly all of the studies under experimental conditions it was impossible to adjust climate control individually for the different density treatments. Thus, density effects reported in these studies may be magnified or caused by increased temperature, humidity or litter moisture. Such an influence will be more pronounced in studies performed in hotter or more humid seasons or locations, and would thus lead to differences between studies. It is important to bear in mind that regardless of whether it is density or environmental factors affecting welfare of broilers these factors often coincide under commercial conditions. Hence measures of welfare that give reasons for concern may in the commercial situation lead to actions taken to reduce density and alleviate environmental deficiencies simultaneously.

A relation between stocking density and climate is likely to be less expressed when small groups of animals are housed at different densities within the same room (as is the case in many experimental

studies). Such a setup will allow air circulation from one density to another, decreasing differences in temperature and humidity between the treatments. Buijs et al. (2010) found only a minimal (2ºC) difference between temperatures measured at a density of 6 kg/m² and at 56 kg/m² when several small groups of 8-72 birds were housed in the same room. No significant differences in temperature occurred within the range of 23 to 56 kg/m², and humidity and air ammonia did not differ between any of the treatments. Furthermore, it is unclear if adjusted climate control would fully prevent a density-induced increase in temperature, humidity and litter moisture, since ventilation of the litter surface is impeded when a large proportion of the floor is covered by densely stocked broilers near the end of rearing (Bessei, 2006).

1.5.5.1. Effects of stocking density on growth rate

In the 2000 report, a critical stocking density for growth depression was estimated around 30 kg/m2, but improved ventilation was suggested to alleviate this effect. Many authors have since reported decreasing growth rates with increasing density (e.g., (de Oliveira et al., 2000; Al Homidan and Robertson, 2003; Thomas et al., 2004; Dozier et al., 2005; Dozier et al., 2006; Sirri et al., 2007; Villagra et al., 2009; Beloor et al., 2010; Petek et al., 2010; Sekeroglu et al., 2011; Simsek et al., 2011; Zuowei et al., 2011; Benyi, 2012). The critical density for decreased growth indicated by these studies varied greatly, from as low as 17 kg/m2 (Thomas et al., 2004) to as high as 46 kg/m2 (Dawkins et al., 2004). Others found no effect of stocking density on growth although a wide range of densities was included (e.g., (Buijs et al., 2009): 6-56 kg/m2; (Ventura et al., 2010): 21-48 kg/m2).

1.5.5.2. Stocking density, feed intake and feed conversion

Motivation to feed is perhaps the strongest motivation in broilers (Bokkers and Koene, 2004). If birds are not able to feed to the extent they are motivated this may lead to frustration and impaired welfare. It is therefore highly relevant to discuss reduced feed intake and the causes of this reduction in poultry production. In line with the 2000 report, several authors found that feed intake decreased with increasing density (Al Homidan and Robertson, 2003; Bokkers and Koene, 2004; Thomas et al., 2004; Dozier et al., 2005; Villagra et al., 2009; Beloor et al., 2010; Benyi, 2012). However, several other studies found either no response of feed intake to density (de Oliveira et al., 2000; Imaeda, 2000; McLean et al., 2002; Ravindran et al., 2006; Sirri et al., 2007; Turkyilmaz, 2008), an increase in feed intake with increasing density (Zuowei et al., 2011), or peak values at intermediate densities (Feddes et al., 2002). Such contradictions between studies cannot be explained by a focus on different parts of the density scale, as contradictions were also found between studies focusing on similar density ranges. The studies showed no clear association between feeder space per bird and feed intake either. Evidence on food conversion ratios is similarly contradictory, with some studies indicating worse (i.e., higher) ratios at higher density (Dozier et al., 2005; Dozier et al., 2006); (Sirri et al., 2007; Zuowei et al., 2011), whilst others found no effect (Imaeda, 2000; McLean et al., 2002; Thomas et al., 2004; Turkyilmaz, 2008; Villagra et al., 2009; Beloor et al., 2010; Petek et al., 2010; Ventura et al., 2010; Sekeroglu et al., 2011) or even an improved ratio (de Oliveira et al., 2000).

1.5.5.3. Stocking density and mortality

Recent research supports the lack of a density effect on mortality described in the 2000 report (Feddes et al., 2002; Dawkins et al., 2004; Thomas et al., 2004; Dozier et al., 2005; Dozier et al., 2006; Ravindran et al., 2006; Sirri et al., 2007; Meluzzi et al., 2008; Turkyilmaz, 2008; Buijs et al., 2009; Villagra et al., 2009; Petek et al., 2010; Ventura et al., 2010; Sekeroglu et al., 2011; Zuowei et al., 2011). High stocking densities may even decrease mortality in the first weeks of rearing (Heier et al., 2002; De Jong, 2010) which may be the effect of higher temperatures at chick level although this needs further study. However, mortality may increase with stocking density under exceptionally hot conditions (de Oliveira et al., 2000; Imaeda, 2000).

1.5.5.4. Stocking density and pathologies

Recent research on the relation between stocking density and pathologies has mainly focused on dermatitis, walking ability and leg deformations.

In line with the 2000 report, several recent studies under experimental conditions indicate increased footpad and hock dermatitis with increasing stocking density (Sorensen et al., 2000; Hall, 2001; Thomas et al., 2004; Dozier et al., 2005; Dozier et al., 2006; Buijs et al., 2009; Villagra et al., 2009; Petek et al., 2010; Ventura et al., 2010; Spindler and Hartung, 2011; Zuowei et al., 2011). This is likely to be at least partly caused by deterioration of litter quality with increasing stocking density (McLean et al., 2002; Thomas et al., 2004; Dozier et al., 2005; Dozier et al., 2006; Ravindran et al., 2006; Petek et al., 2010). In contrast, several epidemiological studies suggest that in practice such stocking density effects may often be overshadowed by other sources of variation, as no relation between density and dermatitis was found (Martrenchar et al., 2002 ; Dawkins et al., 2004; Meluzzi et al., 2008; Allain et al., 2009). This is further supported by Hepworth et al. (2010) who found that stocking density at placement of broiler chicks was not a reliable predictor of hock burns, whereas stocking density (weight/m^2) at five weeks of age was positively associated with the incidence of hock burns. This indicated that management factors, in addition to stocking density, during the rearing period of the birds are crucially affecting the health of the birds. It is possible that the increase in skin scratches at higher densities may be related to increased disturbances (Hall, 2001; Cornetto et al., 2002; Dawkins et al., 2004; Febrer et al., 2006; Buijs et al., 2010; Ventura et al., 2012), as birds may inflict scratches on other birds by walking over their backs as they search for places to rest, feed or water.

Significantly decreased walking abilities have been reported from a critical density of 33 to more than 42 kg/m^2 (Sorensen et al., 2000; Dawkins et al., 2004; Thomas et al., 2004; Buijs et al., 2009; Zuowei et al., 2011). However, even at densities below this point walking ability may be compromised, as Buijs et al. (2009) found a steep decrease between 6 and 23 kg/m^2. Evidence for a decreased walking ability at increased density found under experimental circumstances is supported by studies on commercial farms (Dawkins et al., 2004; Knowles et al., 2008).

Sorensen et al. (2000) and Dawkins et al. (2004) found no effect of stocking density on leg deformations, but Buijs (submitted) reported increased tibia curvature and decreased bone strength at higher densities. No effects of density on fractures (Sirri et al., 2007), bone ash percentage (Tablante et al., 2003), or tibial dyschondroplasia (Sorensen et al., 2000); Buijs, submitted) have been found.

1.5.5.5. Stocking density and physiological parameters

The available information on physiological changes in response to increased stocking density has increased greatly since 2000. For instance, many blood parameters indicative of increased stress levels have been studied. Two of these parameters suggest that stress levels start to rise starting at a density of 8 or 9 birds/m^2 on, i.e, heterophil/lymphocyte ratio of birds near slaughter age (Thaxton et al., 2006a; Onbasilar et al., 2008; Villagra et al., 2009), although this has not been found in Heckert et al. (2002), and total plasma protein was unchanged (Sekeroglu et al., 2011). For some other blood parameters the evidence is inconsistent. Higher levels of serum glucose (Onbasilar et al., 2008; Zuowei et al., 2011) and cholesterol (Onbasilar et al., 2008) were reported for densities of 18 birds/m^2 than for 12 birds/m^2, but other studies found no effect (Dozier et al., 2006; Thaxton et al., 2006a). Corticosterone levels and stocking density were not related in most studies (plasma corticosterone: (Dozier et al., 2006; Thaxton et al., 2006a; Turkyilmaz, 2008), faecal corticosterone: (Dawkins et al., 2004; Buijs et al., 2009) . However, (Villagra et al., 2009) found a lower plasma corticosterone value at 20 than at 8 or 30 birds/m^2. Several other stress-related blood parameters were not found to be affected by stocking density in any study in which they were measured, including: heterophil/lymphocyte ratio as measured before an age of six weeks (Heckert et al., 2002; Dozier et

al., 2006; Villagra et al., 2009; Petek et al., 2010), haematocrit values (Villagra et al., 2009; Petek et al., 2010), response to sheep red blood cells (Heckert et al., 2002; Onbasilar et al., 2008) response to Newcastle Disease Virus (Turkyilmaz, 2008), nitrate concentration (Dozier et al., 2006; Thaxton et al., 2006a), lymphocyte blastogenesis (Heckert et al., 2002) and white and red blood cell counts (Petek et al., 2010; Sekeroglu et al., 2011). Furthermore, the density and social context at which the breeding birds are kept also affect the immune system of the broilers, in that an increased density reduced the maternal antibody transfer to the embryo chick (Leandro et al., 2011).

In addition, organ weights, fearfulness, telomere length and gene expression have been studied at different densities. Decreases in relative Bursa of Fabricius and spleen weight with increasing density suggest stress-induced immunosuppression (Heckert et al., 2002; Ravindran et al., 2006), but other authors found no effect of density on bursa weight (Onbasilar et al., 2008; Buijs et al., 2009) spleen weight (Onbasilar et al., 2008; Sekeroglu et al., 2011), or adrenal weight (Thomas et al., 2004). Shorter telomere length at 17 than at 9 birds/m^2 suggests increased oxidative stress (Beloor et al., 2010). In addition, the expression of the genes coding for HSP70 (a heat shock protein, increased levels indicating heat shock or other stressors) and HMGCR (a rate limiting enzyme in cholesterol biosynthesis, which in turn influences corticosterone) were increased at 17 birds/m^2 as compared with 9 and 13 birds/m^2 (Beloor et al., 2010).

1.5.5.6. Stocking density and behaviour

Behavioural test indicate that fear levels are elevated at high density. Tonic immobility (TI) duration was found to be elevated from a density of 18 or 22 birds/m^2 onwards (Onbasilar et al., 2008; Buijs et al., 2009), though Ventura et al. (2010) did not find any relationship between TI duration and densities from 8 to 18 birds/m^2. Where an effect was found, it was to be limited to male broilers (Buijs et al., 2009; Villagra et al., 2009).

The 2000 report described conflicting experimental results concerning the effect of stocking density on behaviour. For some types of behaviour, recently reported effects are also inconsistent. The time spent on locomotion was found to decrease with density in some studies (Hall, 2001; Leone and Estevez, 2008; Ventura et al., 2012) but was unaffected in others (Cornetto and Estevez, 2001a; McLean et al., 2002; Collins, 2008). Febrer et al. (2006) and Buijs et al. (2011b) reported that although the total time spent walking did not decrease with increasing density, individual walking bouts were shorter. Litter directed behaviour was decreased with increasing density in some studies (Hall, 2001; Buijs et al., 2011b);(Ventura et al., 2012) but not in others (Cornetto and Estevez, 2001a; McLean et al., 2002; Febrer et al., 2006) . The contradictions concerning locomotion and litter directed behaviour were not due to the inclusion of different density ranges in the opposed studies.

Most studies housed the same amount of birds/m^2 throughout the rearing period. However, since EU regulations stipulate a maximum in kg/m^2, it is possible to house an increased number of birds/m^2 when they are younger and thus lighter. (De Jong, 2010) stocked broilers at a maximum of 80 birds/m^2 during the first two weeks of rearing, and to a maximum of 50 birds/m^2 during the first three weeks of rearing. Increased density led to decreased locomotion and litter directed behaviour. Bokkers et al. (2011) modelled the space needed for broilers to perform different behaviours at different stocking densities. They found that broilers were physically compressed at densities above 16 birds/m^2 or 39.4 kg/m^2. They also recognised the fact that they only modelled the physical space needed and gave no estimation of the social space that might be needed to perform certain behaviours (Bokkers et al., 2011).

There is one aspect of behaviour for which recent studies showed a consistent effect of stocking density: broilers are increasingly disturbed by each other as density increases (Hall, 2001; Cornetto et al., 2002; Dawkins et al., 2004; Febrer et al., 2006; Buijs et al., 2010; Ventura et al., 2012). Together, these studies suggest that there is likely no specific critical density for increased disturbances, but that

disturbance increases gradually over a wide range of densities. These disturbances have been suggested to be the cause of the fragmentation of resting and preening bouts with increased density (Hall, 2001; Buijs et al., 2010; Buijs et al., 2011b).

In contrast with the decrease in feed intake with increased density mentioned above, none of the recent studies found effects of density on eating or drinking behaviour (Hall, 2001; Febrer et al., 2006; Buijs et al., 2010; De Jong, 2010; Buijs et al., 2011b; Ventura et al., 2012). At least in part of these studies feeder and drinker space per bird were kept constant.

In addition to changes in the behavioural repertoire, effects of density on broiler use of space have also been studied. In a study comparing a density of 2 birds/m^2 with 15 birds/m^2, it was shown that at the low stocking density broilers preferred to stay near the feeders and drinkers, whereas at the high density broilers stayed in the 'free area' of the pen (Arnould and Faure, 2003). Ventura et al. (2012) showed that broilers used the central areas of experimental pens less often as density increased from 8 to 13 and 18 birds/m^2, indicating that higher densities discouraged a more even distribution of birds throughout the available space. The spatial distribution of broiler chickens has also been used to determine at which density crowding becomes aversive. Although Febrer et al. (2006) suggested that broilers were attracted to each other even at high densities (indicating that these densities did not lead to an aversive level of crowding), this study did not take into account that how broilers distribute themselves is also determined by environmental factors (e.g., local climate, feeder position). When such environmental factors were accounted for, Buijs et al. (2011b) found that broilers stocked at a target weight $\geq$ 15 kg/m^2 avoided each other, suggesting that they experienced the proximity of their conspecifics as aversive. In addition, broilers were found to be willing to work relatively hard to achieve densities below 40 kg/m^2, suggesting they were strongly motivated to achieve their preferred lower density (Buijs et al., 2011a).

1.5.5.7. Conclusions

1. Although high stocking density has a negative influence on many aspects of broiler welfare, it is unclear to what extent these are in fact attributable to environmental factors that deteriorate with increased density (temperature, humidity, litter moisture). Also, it is unclear to what extent it is possible to prevent such a deterioration using improved climatic control, since air may be trapped between birds when they are stocked densely.

2. Large variation in environmental factors may obscure density effects studied in the field. However, even studies on commercial farms showed a decrease in growth rate and walking ability as stocking density increased, and increased disturbance of rest, as well as an increase in skin scratches, hock burn and foot pad dermatitis as stocking density increased which are all indicative of decreased welfare.

3. Studies on bird distribution, avoidance and motivation for birds to achieve lower stocking densities indicate that broilers prefer stocking densities that are lower than the maximum stocking density as indicated in the EU Broiler Directive.

1.5.6. Stockmanship

Many studies on the relationship between stockperson behaviour and the productivity and welfare of animals have been carried out in dairy cattle and pigs. But also in broilers it has been shown that there is a relationship between the behaviour of the stockperson and the behaviour of the animals (Hemsworth, 2003). In a study where broilers were subjected to regular visual contact with humans or no visual contact (control group) it was shown that regular visual contact from 1 to 21 days of age reduced fear and stress reactions to handling and crating, and improved the antibody response to Newcastle Disease vaccine (Zulkifli et al., 2002).

Studies found negative correlations between fear of humans and productivity in meat chicken industry (Hemsworth et al., 1994; Cransberg et al., 2000). There is evidence that animals fearful of humans are likely to experience acute stress in the presence of humans or even chronic stress in some situations. This chronic stress in fearful animals may also lead to immunosuppression, which in turn may have serious consequences for the health of the animals (Hemsworth, 2003).

1.5.6.1. Conclusions

1. The role and impact of the stockperson on animal welfare and productivity is paramount – also in broiler production.

2. There are indications that regular stockperson visual contact reduces fear and stress in broilers.

1.5.7. Environmental enrichment

Commercial broiler chickens are typically reared in low complexity environments, where required foraging effort and travel distance to access feed and water is low, and movement and activity is restricted by the presence of other birds in the path of movement (Newberry and Hall, 1990; Èstevez, 1997; Estevez and Christman, 2006). These environments - composed of litter-covered floors, uniformly coloured walls, feeders, drinkers, and (sometimes) heaters - provide minimal stimulation.

Environmental enrichment interventions have been shown to be useful in addressing management problems that impair broiler welfare. However, caution is recommended, as certain types of interventions may either be useless or create unwanted effects (Jones, 2004). It is important to remark that devices and environmental modifications must be functionally relevant to the birds if they are to yield benefits for welfare (Newberry, 1995).

To be effective, enrichment should: 1) maintain the sustained interest of the birds, 2) increase the occurrence of desirable behaviours, 3) decrease detrimental behaviours and 4) be practical to implement (Jones, 2004). From a practical stand point enrichment devices should ideally be long lasting, easy to disinfect across successive flocks, and easy to integrate within the environment.

1.5.7.1. Perches

Use is factor-dependent
Past efforts to offer different perch designs to broilers have tended to see infrequent use (between 1.0-2.6% of birds on average (LeVan et al., 2000; Su et al., 2000; Pettit-Riley and Estevez, 2001). However, perch use appears to vary depending on factors, such as breed, gender, time of day, density, and design of the perch. Ultimately, perches may be more appropriate in some situations and less in others.

Generally slow growing birds use perches more frequently as compared with fast growing birds. Bokkers and Koene (2003a) found that slow growing birds (i657 strain) perched more than fast growing birds (34 vs. 20% during the first six weeks of rearing). Nielsen (2004) found that birds of the slow growing i657 strain perched considerably more than birds of a slow growing Labresse strain (24% vs. < 1% at midnight at 11 weeks of age). Estevez et al. (2002) also found gender differences with females using perches at a higher frequency as compared to males.

Degree of perching is also heavily influenced by time of day. Most broiler studies characterized perching behaviour during daytime hours only (Lee and Chen, 2007; Ventura et al., 2012), though LeVan et al. (2000) recorded until 22:00h and noted higher perching into the evening hours. Nielsen (2004) did 24h recordings, and found a clear circadian perching rhythm with virtually all perching occurring from 30 min after sunset until 1 h before sunrise.

Perch availability was thought to help to minimize negative consequences of stocking density, however the results of perch used with density are unclear. Pettit-Riley and Estevez (2001) reported a stimulating effect on perch use of increasing density from 10 to 15 birds/m^2, whereas Ventura (2009; Ventura et al., 2012) observed higher perch use at 8 birds/m^2 as compare with 13 and 18 birds/m^2. Results may diverge because in Pettit-Riley and Estevez (2001) study perch use was relatively low, therefore there was available perch space for a larger proportion of the birds to perch at higher densities. On the contrary, in Ventura et al. (2012) study perch used peak at 20% for the two highest densities. It is likely that perch space saturation may have occurred in the study of Ventura et al.(2012) as perch space was not provided to grant access to all the birds. When birds of the i657 strain had access to half the total perch length at the same group size (15 vs. 7.5 cm/bird), perching was found to be reduced considerably (24% vs. 7% perching at midnight) (Nielsen, 2004).

Types of perches

Design is a critical factor influencing perching rates in broilers. Higher perching rates were reported in studies using wooden perches (10-25%) (Bizeray et al., 2002a; Bokkers and Koene, 2003a; Ventura et al., 2012) than in those using PVC pipe perches (<2.6%), (LeVan et al., 2000; Pettit-Riley and Estevez, 2001), although such differences may also be explained by the fact that the wooden perches were lower and horizontal.

Low wooden perches were also found to reduce aggression and disturbance, likely due to changes in the way birds use the available space (Ventura et al., 2012). Wooden perches, however, did not have clear beneficial effects on leg health, fear or hock lesions (Bizeray et al., 2002b; Ventura et al., 2010), although Ventura et al. (2010) found a near significant improvement on the severity of the foot pad lesions. Although effects of wooden perches on behaviour and some leg parameters were studied at industry-relevant densities (Bizeray et al., 2002a; b; Ventura et al., 2010), this type of perch has not been studied in commercial settings. Incidentally, Nielsen (2004) found the highest incidence of breast blisters among the broiler strain that did not use the perches, indicating that differences in susceptibility between strains play a role for this condition rather than perching.

Perch use may be improved by water-cooling in warm environments. Estevez et al. (2002) found that 8% of birds perched on cooled iron perches, whilst only 4% perched on non-cooled iron perches during the last week of rearing.

Broilers also perch on straw bales, which additionally stimulate walking and running and may create a more even distribution of birds throughout the house by attracting birds (Kells et al., 2001).

General considerations

As with general activity levels, perch use in fast-growing strains tends to peak around 3-5 weeks of age and declines thereafter (LeVan et al., 2000; Pettit-Riley and Estevez, 2001; Bokkers and Koene, 2003a; Ventura et al., 2012), so it is important to retain perches at least at least until the 5th week of age for these birds.

Perches of various designs did not appear to affect production characteristics including final body weight, feed conversion and mortality (Pettit-Riley and Estevez, 2001; Heckert et al., 2002; Ventura et al., 2010)

1.5.7.2. Visual barriers

Vertical Cover Panels

The idea of providing artificial protective cover in the form of vertical pen partitions was first tested by Newberry (1997). Vertical cover panels have been shown to break up aggregations of broilers around walls and promote more uniform bird distribution (Cornetto and Estevez, 2001b), leading to multiple benefits including reductions in aggression and disturbances (Cornetto et al., 2002) and increases in net distance travelled (Estevez et al., 2010). In broiler breeders raised in commercial conditions, vertical panels have been shown to increase male home ranges in addition to their beneficial effects on reproductive performance, which can translate into economic benefits (Leone and Estévez, 2008).

Visual Barriers
Broilers reared in environments that foster maximum occlusion experience (familiarity with the disappearance and reappearance of objects) via the provision of opaque screens exhibit more activity upon release into a novel environment and seem to orient better to out-of-sight goals, suggesting possible improvements in spatial memory that could have implications in enhancing bird navigation throughout the pen space (Freire et al., 2004).

1.5.7.3.   Other enrichment devices

Other types of devices have been used to enrich the poultry environment.

Items designed to redirect activities
Providing string devices has been a successful approach to reduce feather pecking and damage in both experimental and commercially raised layers (Jones et al., 2004; McAdie, 2005) although an experiment with female broiler breeders did not report extensive use of string bundles in a commercial setting (Hocking and Jones, 2006). Neither did provision of strings to broilers in an experimental setting (Arnould et al., 2004). It is possible that string devices may benefit layers more than broilers. Trays with sand attracted birds to pen area that were otherwise rarely used and promoted a more uniform bird distribution (Arnould et al., 2004).

Items designed to encourage foraging behaviour
Commercially reared broilers provided with a cereal-based enrichment device called the Pecka-block™ showed less pecking and more dust bathing and litter scratching behaviour (Guy and Wright, 2003). Scattering feed pellets in the litter was found to increase walking and foraging (Jordan et al., 2011). On the other hand, attempts to stimulate foraging by dispersing whole wheat kernels (Bizeray et al., 2002a; Jordan et al., 2011) or with brightly coloured moving lights projected onto pen floors (Bizeray et al., 2002a) seem to have little behavioural effect. More effective interventions to stimulate activity and reduce leg disorders have been observed with the use of treadmills (Reiter, 2006) , though the applicability of this on a commercial scale is probably low.

Toys
Toys (e.g., a ball, a mirror, a boot) have been provided in an attempt to stimulate activity, but these had only short-term effects and are probably not effective in maintaining the long-term interest of the birds (Bizeray, 2004). If toy-like objects have a beneficial function, it may be rather as a source of familiarity, which may serve to mitigate fear levels. The reduction of fear should be an important goal of enrichment for broilers as excessive fear reactions can have harmful effects such as panic, though more moderate fear reactions are also detrimental to bird welfare (Jones, 1996).

1.5.7.4.   Sensory enrichment

Visual stimuli
Another way to increase the complexity of the birds' environment is to add video images. Birds may be attracted to complex, brightly coloured and moving images projected onto pen walls (screensaver programmes), even if they have no significance for the birds (Jones, 1996; Jones, 2004). Further

research is warranted to ensure that these additions do not create fear and avoidance, and to determine if images yield benefits beyond simple attraction (Newberry, 1995).

Though lighting programs should probably be considered as management techniques rather than as enrichment *per se*, reducing photoperiod has been used to stimulate activity levels (Reiter, 2006). However, care should be taken, as extended dark periods can affect behavioural rhythm (Reiter, 2006). Increased light intensity was found to increase activity in the light phase whilst decreasing it in the dark phase (Alvino et al., 2009b; Blatchford et al., 2009), and to lead to longer uninterrupted resting bouts in the dark phase due to increased behavioural synchronisation (Alvino et al., 2009b). Providing bright red light was found to increase walking, feeding and stretching, particularly when applied early in the growth period (Prayitno et al., 1997).

Odours

Sense of smell in chickens has been underestimated and may provide an interesting avenue for enrichment. Chicks demonstrate sensitivity and changes in feeding behaviour after prenatal exposure to odorants (Bertin et al., 2010). The application of familiar odours may be especially helpful in reducing fear. For example, chicks raised in the presence of vanilla exhibit reduced fear responses in an open field containing the odour (Jones et al., 2002). Thus familiar odours appear to have a fear-reducing potential, but potential benefits of this approach have not been thoroughly investigated.

Music

Although there is some interest in understanding the role of music (e.g. radio) in reducing aggression and improving health (Jones, 2004), there is little experimental work that addresses this specific issue for broilers.

Layer hens raised in cages and exposed to classical music exhibited a decreased stress response (lower heterophil/lympocyte ratios and higher relative symmetry in morphological traits), but showed no change in fear response (as measured by tonic immobility (Davila et al., 2011)). On the other hand, another experiment reared layer hens in floor pens and showed an increased fear response with classic music exposure (Campo, 2005).

Overall, the effect of music as a beneficial enrichment for poultry, and especially for broilers, remains unclear.

1.5.7.5.   General considerations

Some of the above-reviewed environmental enrichment has the potential to yield welfare benefits for broiler chickens, though further work is necessary for its potential application under commercial broiler operations.

From other species it is known that it is important to provide access to enrichment near the start of life in order to minimize fear reactions to novelty and to ease uncertainty (Wechsler and Lea, 2007), as is the case with broiler breeders (Estevez, 2009). Providing laying hen chicks with early access facilitates increased use of the enrichment (Heikkila et al., 2006), which is probably also the case in broilers. When using enrichment, it should be kept in mind that a certain level of novelty is surely stimulating for the animal but that too much novelty can be very frightening. Also, items intended as enrichment, but which have no positive effect on the birds, may reduce available space without conferring a benefit.

1.5.7.6. Conclusions
  1. Enrichments are additions to the birds' environment that improve the welfare of the birds, e.g., by providing birds with cover, or by encouraging activity and desirable behaviours like

perching. Perches should be considered as potential enrichment, although their use depend on factors like breed or especially perch design. Low horizontal barriers show particular promise in encouraging perching behaviour in fast growing strains.

2. Although enrichment is a promising area for research to improve broiler welfare, benefits should not be generalized, as results of the intervention may depend on multiple factors. Further research is needed to refine enrichment design in such a way that materials used are long lasting, easy to disinfect among successive flocks and are easy to apply.

3. Pilot studies under commercial conditions are required before their use can be recommended on a large scale.

1.5.8.   Broiler catching

In an epidemiological study on a large number of Dutch and German broiler flocks it was shown that catching company was one of the risk factors for Dead-on-Arrival (Nijdam et al., 2005). Catching broilers with a sweeper-type catching machine compared with manual catching at commercial farms significantly reduced the number of injuries in the birds, especially leg injuries (Knierim and Gocke, 2003). The authors of this study stressed that familiarisation of the catching team with the machine took some time and is something that should be improved (Knierim and Gocke, 2003). A comprehensive study of the sweeping system of Berry and Parry was compared with manual catching at a United States commercial broiler farm (Thaxton et al., 2006b). This work found slightly elevated corticosterone levels in mechanically caught broilers when compared to manually caught birds. In all other parameters tested, (microbiology, physiology and meat quality) there were no significant differences. Others compared mechanical catching with the CIEMME Super Apollo L harvester with manual catching under commercial conditions. At the end of the catching process, mechanically caught broilers had lower plasma corticosterone concentrations and shorter durations of tonic immobility as compared to manually caught broilers. The proportion of wing haemorrhages was also reduced in mechanically caught broilers (Delezie et al., 2006).

1.5.8.1. Conclusions

1. Several studies compared manual catching with mechanical catching. If carried out properly, both methods may result in low levels of stress and injury. Some studies indicate that mechanical catching may lead to less injuries as compared to manual catching.

1.6.   Nutrition and feed management (including water)

In this section, parts of the original text of the report on the welfare of chickens kept for meat production (SCAHAW, 2000) are included.

1.6.1.   Performance

The general objective of broiler nutrition is to maximise the economic production performance of broilers. Diets are formulated by least cost linear programming to provide specified levels of nutrients that are needed for optimum performance. The main production criteria are body weight, feed conversion, health and body composition, aiming at fast, efficient, and lean growth at low morbidity and mortality levels.

Diets are usually compounded from cereals, such as wheat and maize, as the principal source of energy and protein rich ingredients such as oilseed meals, pulses and animal proteins (primarily fish meal). Vegetable fats are added as additional sources of energy and diets are routinely supplemented

with a range of additives, including minerals, vitamins, amino acids, and enzymes. The main components of diets are usually added in ground or flaked form but after the diets have been mixed, they are formed into pellets. Feeding diets as pellets has two advantages. Firstly, it improves feed intake and the efficiency of eating. Secondly, the pelleting process involves heating the feed, usually by treatment with steam, which has the added benefit of killing pathogenic organisms that may be present in the raw materials. Indeed, higher temperatures and length of exposure to these temperatures have been introduced in recent years during the different stages of feed compounding with the specific aim of eliminating this contamination. These treatments can degrade some of the dietary constituents, so higher levels of some nutrients, such as vitamins, may be added to diets beforehand in compensation and other dietary components such as enzymes may be added in liquid form after pellet production. Feed is given as small crumbs to newly hatched chicks but as larger pellets to older birds.

Birds are able to discriminate between food sources and, when offered a choice between feeds, can select a mixture of the major nutrients, such as energy and protein, that is broadly appropriate for their individual needs. True choice feeding, where the birds can select from separate food sources, is rarely used commercially, partly because of the cost of having to provide separate feeding systems. However, birds are able to exercise a degree of selection under feeding practices common in some countries that involve mixing of whole wheat in with standard pelleted broiler feeds (e.g., UK 12-15%, DK, from 5-7% in starter diets to 25-30% in finisher diets). This practice has several advantages. It saves milling costs of the wheat and gives as good performance as could be achieved by feeding the pellets alone. The reason for the good performance under these conditions is not fully understood, but may be related to better overall digestion resulting from longer retention of feed in the gizzard (Hetland et al., 2002) and the presence of endogenous enzymes that would normally be destroyed during heating of wheat. In addition, whole wheat feeding seems to improve gut health by stimulating gizzard function. With higher hydrochloric acid secretion and lower pH, the gizzard can be regarded as a barrier organ in the prevention of pathogenic bacteria entering the distal intestinal tract (Engberg et al., 2004). More sophisticated feeding systems are also available that can adjust the balance between whole wheat and a complete diet in the broiler house on a daily basis. These systems use measurements of body weight and feed intake as a basis for calculating the optimum nutrient balance needed to maintain the desired level of performance.

Selection for increased growth rate is accompanied by increased requirements for food resources. A study investigated the hypothesis that more intensive selection for growth in some lines of broilers has altered feeding behaviour by analysing short-term feeding bouts in relation to the roles of hunger and satiety mechanisms in the control of food intake. Overall, it is apparent that even when growth rate and body size have been substantially altered by genetic selection, the underlying normal controls of feeding behaviour are conserved in broiler birds (Howie et al., 2009).

1.6.1.1.   Energy and protein

The energy, protein and amino acid contents of the diet are major factors determining the growth, feed efficiency and body composition of broilers. Diets of high energy content promote fast growth, so metabolisable energy (ME) contents are generally not less than 12.5 MJ/kg. As birds grow, the proportion of the feed needed for body maintenance increases. Thus starter diets usually have relatively high crude protein (CP) content (220-230 g CP/kg) whereas finisher diets may contain only 160-180 g CP/kg, depending upon the age to which the birds are grown. However, there are considerable variations in the nutrient compositions of commercial diets fed at different stages, for a number of very different reasons. In the countries in northern Europe where whole wheat feeding is common practice, the whole wheat are used in increasing amounts during the growth period mixed with concentrated compound feed (finisher diets can range from 220-250 g CP/kg).

The amount of protein needed to provide the required amino acid content and balance will depend upon the amino acid composition of the feed ingredients and the availability and cost of synthetic amino acids. Protein is a relatively expensive component of a diet and the requirement for the first limiting amino acid increases nearly in direct proportion to the CP content of the diet (Morris et al., 1999). As an example, a 25 g/kg reduction of CP content of the diet can only be obtained without adverse effects on performance and body composition when Glycine and Glutamic acid was supplemented to the reduced-CP diets, which implies a need for nitrogen for the synthesis of nonessential amino acids (Berres et al., 2010). It is therefore a desirable practice to formulate diets to meet the individual amino acid requirements at the lowest economical CP content. Failure to meet the requirement for an amino acid can result in depressed growth but without the appearance of any specific lesions.

Broilers have an appetite for both protein and energy and will regulate food intake to meet their needs for both of these nutrients. Thus a bird will over consume a diet marginally deficient in protein or an amino acid in order to optimise its intake of the limiting nutrient. Overconsumption of energy will be a consequence of this adaptation, with the excess energy being deposited as fat. Conversely, a bird will consume less of a diet containing a high protein content and will have an improved feed conversion and be leaner. Manipulation of the dietary ME/CP, particularly in finisher diets, is used as a means of controlling the body fatness of market broilers (Jackson et al., 1982). The growth and body composition of broilers during different periods can thus be regulated by altering the dietary contents of protein (and amino acids) and energy. This practice is not considered to have any detrimental welfare effects, even though a broiler may not reach its maximum potential weight for a given age. It may even be beneficial for a broiler not to achieve its maximum growth potential, given the association between fast growth and a number of metabolic disorders (See 1.6.2. also 2.1.5.).

1.6.1.2. Fat and fatty acids

Broilers have a dietary requirement for essential fatty acids (EFA). The main EFA is linoleic acid, which acts as a precursor for other members of the n-6 series such as arachidonic acid and derived prostaglandins. Birds also appear to have a much smaller requirement for fatty acids of the n-3 (linolenic acid) series. Other body fatty acids (n-9 series) can be synthesised *de novo* from carbohydrate precursors. Specific lesions, particularly in the skin, can result from EFA deficiency if the diet content of linoleic acid falls below the requirement of about 10g/kg. However, this seldom occurs in practice since diet ingredients containing EFAs and supplemental fats and oils are widely used to achieve the high dietary ME values associated with high performance. Beneficial skeletal effects during growth of increased dietary n-3 PUFA:n-6 PUFA (utilising salmon oil) have been demonstrated (Fleming, 2008).

1.6.1.3. Calcium and phosphorus

These nutrients are essential for good bone formation, with bone quality being more sensitive than growth rate as a criterion of the requirements for these nutrients. The balance between these nutrients is also important and the normal contents of starter diets are about 10 g calcium and 4.5 g available phosphorus / kg in the approximate ratio of 2:1. Deficiencies or imbalances of these nutrients can have severe effects on the bone quality and welfare of broilers. The main consequence is rickets, either of the calcium deficiency or phosphorus deficiency type, which can occur when the diet content of either nutrient is too low, or the diet content of one is too high and induces a deficiency of the other. Tibial dyschondroplasia (TD) is less prevalent than in recent years due to selective breeding programmes (see 2.1.2.) but also nutrition plays a role. Tibial dyschondroplasia (TD) is another consequence of an imbalance when the calcium:phosphorus ratio falls below the optimum (Edwards, 1983). Reduction in dietary phosphorus can be achieved without deleterious effects on performance and bone mineralisation if calcium is reduced concomitantly (Rama Rao et al., 2006). Further it has been found

that decreasing the Ca:totalP ratios in diets for monogastric animals improves the efficiency of microbial phytase (Qian et al., 1997).

TD can still occur even under optimum calcium and phosphorus feeding but rickets should be preventable by correct diet formulation. In practice, rickets is often encountered, for two main reasons. Firstly, given the tightness of dietary specifications for calcium and phosphorus, and the importance of avoiding excessive use of phosphorus to minimise pollution, diet contents sometimes fail to meet specifications. Secondly, even when diet contents appear to be adequate, cases of rickets often accompanied by uneven growth within a flock are sometimes seen. These cases are called 'field rickets' and it is suspected that the aetiology may involve malabsorption or interference with vitamin D metabolism caused by infectious agents. Rickets and TD can cause distortions of bone growth that may not be apparent at the time of the deficiency but may show up later in the growing period and result in clinical leg bone abnormality and lameness, even though the bird by then is receiving a normal diet. The cartilage abnormalities can also act as foci for bacterial infections resulting in the more serious welfare problems of osteomyelitis and femoral head necrosis.

1.6.1.4. Other minerals and vitamins

Diets are routinely supplemented with a large number of minerals and vitamins within ranges designed to avoid deficiencies or toxicities. Deficiencies of these nutrients generally result in impaired performance and specific lesions that can be considered to be detrimental to the welfare of the bird. Toxicities are less common, but also impair welfare.

Sodium is a major supplemental mineral, usually in the form of sodium chloride (salt). Deficiency can result in stunted growth and skin and feather abnormalities. Dietary salt concentrations above the optimum can predispose broilers to ascites or the development of testicular cysts that can impair male reproductive function. The dietary balance between the different anions and cations (principally Na^+, K^+ and Cl^-) is thought to influence broiler performance and an optimum value for the balance has been proposed (Mongin, 1977).

Trace mineral supplements usually provide sources of iron, manganese, zinc, copper, selenium and iodine. The amounts of these supplements depend upon the nature and absorbability of the particular compound. Inorganic sources have been commonly used in the past, but organic chelates or complexes are being introduced to provide more absorbable sources for several minerals.

Practical diets have a natural content of the vitamins needed by broilers but not in amounts adequate for normal health and performance. Supplements of all vitamins are therefore routinely added to broiler diets. The amounts required by broilers have been established experimentally and are reviewed regularly. However, these requirement values are the minimum needed under good experimental conditions and the total amounts provided in commercial diets are generally considerably higher than the requirements. These higher amounts are needed to enable birds to cope with the more stressful conditions experienced under practical conditions, to maximise the capacity of the immune system and to take account of any destruction that might occur during diet preparation and storage.

Deficiencies of individual vitamins give characteristic lesions and can also have some general effects. For instance, deficiencies of a number of B-vitamins result in leg abnormalities associated with stunted longitudinal bone growth. However, under modern conditions of good nutritional practice, simple deficiencies of B-vitamins rarely occur. Deficiencies and excesses of vitamins, minerals and minor nutrients may affect leg health. Nutrients of major concern are Vitamin D, calcium and phosphorus. Other vitamins, such as A, E, C, folic acid and several B-vitamins are also of importance (Waldenstedt, 2006).

1.6.1.5. Feed additives

Diets are supplemented with a number of additives aimed at improving performance or health of birds or the nutritive value of the diet. The threat of coccidiosis is ever present in broiler production and is countered by the routine addition of anticoccidial drugs to diets. Different combinations of compounds are used during the production periods in shuttle programmes designed to prevent the build up of resistance to individual drugs within the various species of *Eimeria*. Anticoccidials are essential constituents of broiler diets. Sources of coccidial infection are widespread and without control the disease causes extensive damage to the intestinal tract with resultant impairment in performance, morbidity and death.

An EU-wide ban (Regulation 1831/2003/EC) on the use of antibiotics as growth promoters in animal feed entered into effect on January 1, 2006. Antibiotics have been widely used in animal production for decades. Added in low doses to the feed of farm animals, they improve their growth performance. However, due to the emergence of microbes resistant to antibiotics which are used to treat human and animal infections ("anti-microbial resistance"), the Commission decided to phase out, and ultimately ban, the marketing and use of antibiotics as growth promoters in feed. Antibiotics will now only be allowed to be added to animal feed for veterinary purposes. This decision was based on opinions from the Scientific Steering Committee, which recommended the progressive phasing out of antibiotics used for growth stimulation, while still preserving animal health.

An alternative procedure for modifying gut microflora involves feeding probiotics, cultures of Lactobacilli and other bacteria that have benign intestinal effects. Probiotics can result in performance improvements, though less reliably than antibacterials. Other types of feed additives include organic acids and oligosaccharides. These can help to minimise pathogenic micro-organisms in the feed or their populations in the intestinal tract. Oligosaccharides may also enhance immunological responses. These alternative ways of maintaining bird health are likely to become more important in the absence of specific antibacterials.

Enzymes are another class of feed additive widely used in Europe. A range of enzymes cleaving polysaccharide and protein linkages of food in the digestive system is used to improve the nutritive values of feeds. The breakdown of non-starch polysaccharides that are not normally digested decreases the viscosity of intestinal contents and improves the absorption of nutrients. The main purpose of these enzymes is to improve the performance and feed efficiency of broilers but there are also welfare advantages. Excreta are less sticky, resulting in better litter quality and lower incidences of hock burn or other skin lesions. Phytase is another widely used enzyme that improves the availability of phytate-bound phosphorus. Phytase does not appear to have any negative impact on the welfare of broilers.

1.6.1.6. Conclusions

1. Mixing whole wheat into standard pelleted broiler feeds is common practice in several countries and may have positive effects such as better overall digestion and improving gut health.

2. It is apparent that even when growth rate and body size have been substantially altered by genetic selection, the underlying normal controls of feeding behaviour are conserved in broiler birds.

3. The energy, protein and amino acid contents of the diet are major factors determining the growth, feed efficiency and body composition of broilers.

4. Calcium and phosphorus are both essential for good bone formation and bone quality is more sensitive than growth rate as a criterion of the requirements for these nutrients.

5. Deficiencies of minerals and vitamins generally result in impaired performance and specific lesions that can be considered to be detrimental to the welfare of the bird.

6. Diets are supplemented with a number of additives aimed at improving performance or health of birds or the nutritive value of the diet (e.g. anticoccidial drugs, NSP enzymes, phytase).

1.6.2.   Nutrition and stress

Modifications to diet compositions can be made to help birds cope with stress. For birds reared under climatic conditions giving rise to heat stress, decreasing the CP content of the diet, using synthetic amino acids to maintain amino acid intake, and increasing the proportion of ME provided as fat will help to decrease the heat increment of the feed and metabolic heat production by the bird. Different feeding strategies as restricted feeding, choice feeding or wet feeding may help to reduce negative effects of heat stress, resulting in beneficial effects on performance and health (Syafwan et al., 2011). Adjustments can also be made to supplements. Providing a proportion of the sodium supplement as the bicarbonate can help to maintain optimum blood electrolyte balance. Vitamin C is not an essential nutrient for poultry under normal conditions, but dietary supplementation with this nutrient can help to alleviate some of the metabolic problems of heat stress (Pardue, 1985) and allow the birds to grow better. Increasing the dietary content of other vitamins is also helpful. For other types of stress, such as disease challenges provision of higher amounts of vitamins, especially vitamins A or E, can be effective in enhancing the activity of the immunological system (Tengerdy, 1977).

1.6.2.1. Metabolic disorders

Nutrition can influence the occurrence or severity of several metabolic disorders. Even when the disorder does not have a direct nutritional cause, manipulation of feed composition or supply can help to combat the problem. This is particularly true for conditions such as valgus-varus leg disorders that are linked to fast growth. In broiler chickens selection for rapid growth from approximately 50 g to 2,3 kg in 37 d has inadvertently produced skeletal disorders such as tibial dyschondroplasia, rickets and associated valgus-varus deformities leading to lameness (Fleming, 2008). The occurrence of these problems can be decreased by slowing growth in a number of ways. Providing diets in mash form will result in lower food intake and growth. Slower growth can also be brought about by qualitative or quantitative food restriction as discussed in 8.4. In recent years a reduced prevalence of TD seems to be reported from various sources at the production level as a consequence of an effort from the breeding companies by selecting for reduced occurrence of TD (EFSA, 2010a).

The incidences of cardiac or cardiopulmonary disorders in poultry can also be reduced by slowing growth. Thus feeding mash rather than pelleted diets as well as feed restriction have been reported to decrease the incidences of Sudden Death Syndrome (SDS) (Proudfoot et al., 1982) and ascites (Shlosberg et al., 1991). Modifications of dietary energy and protein contents that slow growth are also effective, though Mollison (1984) have reported a beneficial effect of a high protein finisher diet (240 g CP/kg) in decreasing ascites mortality independent of an effect on growth. Effects of dietary calcium and phosphorus have also been reported. Scheideler et al. (1995) concluded that dietary calcium or calcium:phosphorus above (NRC, 1994) recommendations resulted in increased mortality from SDS. Cardiac damage, such as that caused by mycotoxins, may predispose birds to SDS (Reams et al., 1997) and perhaps also ascites.

Nutritional manipulations that cause water retention or hypertension can increase the susceptibility of broilers to ascites. Thus excesses of sodium salts such as sodium chloride or sodium bicarbonate or other ionic substances in feed or drinking water can give rise to ascites (Shlosberg et al., 1998). Other minerals, including cobalt, nickel and manganese, can cause hypertension resulting from increased

blood haemoglobin concentrations when fed in excess (Martinez and Diaz, 1996) although excess of these nutrients are rare under practical conditions. Higher levels of dietary vitamin C and E along with selenium might be beneficial, as they decrease the free radicals that are generated in birds with ascites (Gupta, 2011). Phosphorus deficiency has been observed to increase mortality from ascites (Julian et al., 1986). This has been explained on the basis that poor rib strength resulting from rickets impairs normal breathing and thus contributes to hypoxia. Nutrition is not the fundamental cause of ascites and optimising diet composition will not prevent ascites. In practice the most useful nutritional measures are to ensure that diets contain a good nutrient balance and in particular do not contain excesses of sodium salts.

Some disorders are linked more directly to nutrition. Fatty liver and kidney syndrome caused considerable broiler mortality in the 1960s and 1970s but is now prevented by dietary supplementation with biotin (Whitehead, 1976). Several nutritional factors have been associated with TD. A decreased calcium:phosphorus ratio in the diet will increase the incidence of TD (Edwards, 1983), but TD is not prevented by an optimum ratio of these nutrients. The dietary balance between the different anions and cations, principally Na+, K+ and Cl-, can also be a factor in the development of TD, with a metabolic acidosis resulting from a high Cl- content being associated with an increase in incidence of TD and alkalosis with a decrease (Hulan et al., 1986; Hulan et al., 1987). However, manipulation of ionic balance has not been shown to be an effective strategy for preventing TD.

Feed contamination with a mycotoxin, fusarochromanone, can result in TD (Walser, 1982) and TD can also be induced experimentally by feeding the drugs thiuram or Disulphiram (Edwards, 1987a) or increasing the dietary content of cysteine (Bai and Cook, 1994). The incidences of TD caused by these factors can be decreased by dietary supplementation with different trace minerals (copper, molybdenum, zinc) but there is no indication that spontaneous TD is linked to a deficiency of these nutrients.

Dietary supplementation with vitamin D metabolites is the most effective nutritional means of preventing TD. Supplementation with 1,25-dihydroxyvitamin D has been shown to prevent TD completely (Edwards, 1990); (Rennie et al., 1993); (Rennie et al., 1995). Another metabolite, 25-hydroxyvitamin D, is also available commercially and can also decrease TD incidence or severity (Rennie and Whitehead, 1996). This metabolite is not so potent as 1,25-dihydroxyvitamin D and its effect is more variable but increased use of this product could contribute to improved leg health in broilers (see 2.1.2.).

1.6.2.2. Nutritional management and food restriction

Food restriction is used routinely in the rearing of broiler breeder stock to limit body weight gain and optimise reproductive performance. This topic is discussed more fully in sub-report C. Qualitative or quantitative food restriction can also be used during broiler growing as a means of improving production efficiency or health.

1.6.2.3. Manipulation of the growth curve

Broilers are generally fed so as to maximise body weight at all ages. However, manipulation of the growth curve by nutritional management can have advantages. Slowing early growth can improve leg bone quality during the important first 3 weeks when bones appear to be most susceptible to the initial development of lesions (Lilburn, 1989). This slowing of growth can be achieved by feeding starter diets of lower nutrient density (e.g. 11.5 MJ ME, 190 g CP/kg). Feeding diets of higher nutrient density during the later period of growth will allow birds to catch up lost body weight, though complete compensation is more easily achieved in birds grown to older ages. However, birds grown in this way usually show lower incidences of leg abnormalities and mortality from cardiovascular problems and improved food conversion over the production period (Raine, 1986).

1.6.2.4. Food restriction

Alterations in the growth profile of broilers can be achieved by food restriction. Various types of restriction have been studied, from severe over a short period to mild over a longer period. Severe restriction early in life has been reported to result in leaner birds with better food efficiency and health, particularly improved leg health and lower mortality from ascites and SDS. The method involves feeding amounts of food sufficient only to maintain body weight for periods of 5 to 6 days commencing at 4 to 6 days of age (Plavnik and Hurwitz, 1991); (Fontana et al., 1992), although this may have negative consequences for welfare as this may cause frustration and hunger on non-feeding days. The birds can catch up lost body weight if kept to older ages (up to 8 weeks) but may not compensate fully if killed at 6 weeks (Su et al., 1999) when the lost body weight can represent the equivalent of 2 extra days of growth. Prolonging the period of food restriction (McGovern et al., 1999) depresses final body weight to a greater extent. Recently a study was performed to test broiler growth control strategy online in field conditions using different target trajectories. Several experiments were conducted, and the best target trajectory has been proven to result in an end weight of 2,616 g and feed conversion ratio of 1.54 for Ross-type birds and an end weight of 2,472 g and a feed conversion ratio of 1.67 for Cobb-type birds (Cangar et al., 2008). The health benefit of improved walking ability has been found to be related to the degree of body weight reduction achieved by the restriction. Thus food restriction programmes allowing more growth during the restriction period (up to 75% of ad libitum growth) are less effective in improving walking ability at 6 weeks (Su et al., 1999).

An alternative food restriction regime involves mild restriction, by about 5%, over a greater part of the production period which can create improved feed efficienty. The explanation for this is that the birds become more efficient at recovering food that has been spilled in the litter. The greater activity of the birds may also result in better leg quality.

1.6.2.5. Meal feeding

Fasting has been reported to decrease the incidence of TD, without causing growth depression, provided the fasts are of approximately 8h duration (Edwards, 1987b). A subsequent comparison of regimes involving providing meals 2, 3 or 4 times daily has confirmed that meal feeding results in improved walking ability. Body weight at 35 days was observed in this case to decline with the frequency of meals, but the improvement in walking ability as assessed by gait scoring was greater than could be accounted for by the reduction in body weight (Su et al., 1999). It is probable that changes in activity or hormonal patterns of birds given meals have a beneficial effect on leg development and quality. The widespread adoption of meal feeding, integrated with the changing of lighting procedures to give longer dark periods, is thought to be a major factor in the improved leg health seen in UK broilers in recent years. The light schedule broiler chickens are kept under affects both their general activity level (Nielsen et al., 2003a) and their feeding behaviour. In a recent study it was concluded that broilers modify their feeding behaviour according to the prevailing light schedule. Eight consecutive hours of darkness reduced growth, but did not affect overall feed conversion efficiency, and did not appear to exacerbate hunger or food pad dermatitis to any great extent (Duve et al., 2011).

1.6.2.6. Nutrition and litter quality

Foot pad dermatitis (FPD) is very common in meat-type poultry. FPD is a contact dermatitis and wet litter is the most likely factor affecting it (Berg, 1998; Mayne et al., 2007; Shepherd and Fairchild, 2010). Nutrition is one of the major factors affecting litter quality. Adverse effects of nutrition on litter quality are suggested. E.g. energy/protein ratio, crude protein content, amino acid balance, crude fat content, type of fat, and dietary electrolyte balance may all play a role in litter quality (Veldkamp and Harn, 2009).

1.6.2.7. Conclusions

1. Good nutrition is important for rearing healthy broilers. Overt nutrient deficiency is rare but more information on optimal dietary specifications for birds under stressful conditions might improve bird health and welfare.

2. Nutritional management can have an impact on metabolic disorders.

3. Nutrition influences litter quality in different ways, i.e. by the energy/protein ration, amino acid balance, dietary electrolyte balance, crude fat content and type of fat, and thus has an effect on the risk to develop contact dermatitis.

1.6.3. Water

The water quality and method of supply can affect welfare. For instance, saline water from artesian sources can add to the salt load in birds and increase the occurrence of ascites. Water supply systems that allow the spillage of water onto the litter can result in poor litter quality, with the attendant risk of foot pad lesions or hock burns (Shepherd and Fairchild, 2010). Drinking nipples are generally used in order to avoid water spillage into the litter. The nipple cup system allows easy access to water and also minimises spillage.

1.6.3.1. Drinkers, water pressure and additives

At moderate ambient temperatures, there is a close positive correlation between water consumption and ad libitum food intake in poultry, on both hourly and daily bases (Savory, 1978). A water supply which is inadequate in terms of production in either volume or number of drinking points will thus reduce both food intake and growth rate. This is important for production, but does not necessarily matter from a bird welfare point of view, as long as ambient temperature is within the thermoneutral zone.

Commercially reared broiler chickens are commonly supplied with drinking water through lines of nipple drinkers that are positioned above the birds' heads to avoid water leaking and spoiling the litter underfoot. This means that the birds have to peck upwards to obtain water, an action that is very different from the 'scoop' action of natural drinking seen when birds drink from troughs or puddles. (Houldcroft et al., 2008) investigated the welfare implications of the drinking behaviour imposed by nipple drinkers. They showed that chickens have no apparent aversion to the taste of tap water, but that they preferred bell drinkers and troughs over nipple drinkers. Chickens had a strong preference for drinking from nipples that are lower rather than higher and when offered a choice between bowls and nipples of the same height, the chickens are indifferent to the method of water presentation. It was concluded that the height at which water is presented to chickens was more important to them than whether they can drink with the natural 'scoop' action. However, the authors stated that while the results might suggest that chicken welfare could be improved by lowering the drinker lines, wet litter causes welfare issues of its own through its effect on hock burn and foot pad dermatitis; they therefore suggested that drinker systems should be designed so that both aspects of welfare (birds able to drink in their preferred way and clean litter) are possible (Houldcroft et al., 2008). In this context, the standard procedure of gradually raising the height of the drinking nipples as the birds grow may need to be reconsidered, also in terms of assuring that the smallest birds in the flocks are still able to access water.

Van Harn (2009) studied the effect of drinker type and water pressure on performance, litter quality and foot pad lesions in broilers. The use of a drip cup underneath a drinking nipple resulted in better performance, growth rate and feed conversion ratio. The use of drip cups also resulted in a better litter quality; the litter was dryer and more friable. Due to the better litter quality fewer and less severe foot pad lesions occurred. Drip cups did not affect gait or walking ability. Lowering the water pressure on

the nipple drinkers to minimize water spillage had no effect on broiler performance measured in terms of growth rate, feed conversion ratio and mortality. However, water intake and water/feed ratio were on average 2.3 and 1.7 % lower, respectively. Lowering the water pressure also improved litter quality which resulted in fewer and less severe hock burns and foot pad lesions, though tigh scratches were more frequent and severe. In commercial practice, acids may be added to the drinking water occasionally (around the moments of switching from starting to grower feed for example, to reduce 'nutritional stress', although scientific evidence is lacking). In a recent study the effect of acidification of drinking water on foot pad dermatitis and hock burn was studied (Van Harn and De Jong, unpublished observations). Adding acids to the drinking water significantly reduced water consumption and increased the dry matter content of the litter, resulting in significantly less foot pad dermatitis and hock burns. However, growth was reduced and feed conversion increased. In addition it was shown that the broilers had a clear preference for water without acids; when given the choice they consumed on average 30% of water with acids added and 70% of water without acids from the first week of age to slaughter.

1.6.3.2. Thirst or water consumption as welfare indicator

It has been shown that there is a relationship between the degree of gait impairment and the level of dehydration in broiler chickens, where the degree of dehydration was related to findings for plasma osmolality. Results indicated that some of the birds in this case study had been deprived of access to water in excess of 60 hours (Butterworth et al., 2002).

It has been suggested that water consumption in l/m of floor area per crop cycle is potentially a beneficial lag indicator, and l/bird/day or l/m^2/day could be lead indicators which relate to bird health and the impact of water consumption on litter quality. However more research should be undertaken to determine whether there is a direct relationship between changes in observed versus expected daily water consumption and health issues such as enteritis and contact dermatitis (Manning et al., 2007).

Sprenger et al. (2009) studied if voluntary water consumption over time could be used as a non-invasive behavioural parameter for assessing thirst in broiler chickens. They concluded that a simple non-invasive test such as water consumption over time to assess thirst in chickens may form the basis of an on-farm test that could be included in integrated animal welfare assessment schemes. However, thus far this animal-based measure is not included in welfare assessment schemes, probably due to practical limitations.

The Welfare Quality® assessment protocol for broilers (Welfare Quality®, 2009) uses the number of birds per drinking nipple, cup or bell drinker as indicator of absence of prolonged thirst. The protocol recommends 10 birds per nipple, 28 birds per cup and 100 per bell drinker. However, this measure does not take into account that small birds might not be able to reach the nipples and die from thirst.

1.6.3.3. Conclusions

4. Broiler chickens prefer drinkers to be at a lower rather than higher position to drink, corresponding to the natural 'scoop' action of drinking.

5. Water spillage should be prevented as it causes wet litter and increases the risk for contact dermatitis. Water spillage can be prevented by drip cups underneath the nipples. Lowering the water pressure, or reducing water intake by adding acids to the drinking water seem to have negative effects on broiler welfare and are not preferred by broilers.

6. A severe gait impairment imposes a risk for dehydration in broilers.

7. Due to practical limitations there are as yet no suitable animal-based measures for thirst in

broilers. Thus far, the number of birds per drinker as used in Welfare Quality® seems the most useful indicator of absence of thirst in practice, provided the drinkers are accessible to all birds.

1.7. Breeding birds

See chapter 3 (sub-report C) for updated information.

2. Update of influence of genetic parameters on the welfare and the resistance to stress of commercial broilers - Sub-report B

This part updates the underlying report: Scientific opinion on the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers (2010, http://www.efsa.europa.eu/en/efsajournal/doc/1666.pdf).

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The content of the report is based only on new available information since the text of the original report (EFSA, 2010).

For some topics, the EFSA report (2010) only contained minimal updated information since the previous SCAHAW report (2000). Where applicable, it is referred to the relevant section of sub-report A for updated information since 2000.

2.1. Overview of the welfare of broilers

2.1.1. Mortality

In a large study applying the Welfare Quality® broiler assessment protocol in Dutch (majority of flocks), British, Belgian and Italian flocks the average mortality (including culling) for standard, fast growing strains was 2.9% (measured on average at 38 days of age) and average mortality for alternative, slower growing strains was 3.1% (measured on average at 54 days of age) (De Jong et al., 2011a). In another study on Dutch flocks (year-round survey on foot pad dermatitis in 386 Dutch flocks) with standard, fast growing broilers the average first week mortality (including culling) was 1.16% and average mortality at slaughter was 2.88% (De Jong et al., 2011c).

According to the Welfare Quality® assessment protocol for broilers (Welfare Quality, 2009) the percentage of culled birds in relation to the mortality ('uncontrolled' death) is used as indicator of absence of disease.

For effects of environmental factors (e.g., light intensity, stocking density, nutrition) on mortality and the relation with metabolic disorders we refer to the paragraphs with updates on these topics.

2.1.1.1. Conclusions

No new or amended conclusions.

2.1.2. Musculoskeletal disorders

Further evidence for a generic link between mass and lameness has been provided by Keppler (2010), who observed higher daily weight gain and body mass to be associated with increased lameness in slow-growing broiler strains raised under organic conditions.

Intensive artificial selection for rapid growth has altered broiler limb muscle architecture as well as increased pectoral muscle mass. Commercial line broilers exhibit decreased pelvic limb muscle mass and increased abductor and medial rotator muscle mass at the hip joint compared to an ancestral species (Giant Jungle fowl) (Paxton et al., 2010). It is hypothesised that the decline in pelvic limb muscle mass may explain reduced locomotor ability in these heavier birds, and the additional hip joint support is likely to reflect postural changes (increased mediolateral displacement typical of broiler gait) (Paxton et al., 2010). Since substantial variability in limb and joint support was observed within the test broiler population it was hypothesised that such anatomical measures could be indicative of increased lameness susceptibility. Al-Musawi et al. (2011) provide evidence for increased myogenic differentiation and growth in the pectoral but not in the gastrocnemius leg muscles of broilers compared to layers. They recommend the use of welfare intervention strategies such as altered egg incubation regimes to promote increased leg muscle mass in broilers. Recent studies concerned with the manipulation of incubation programmes to alter broiler leg health have proved contradictory. Groves (2011) produced birds with greater leg weakness using a 'test' profile (0.5°C warmer, 3% lower relative humidity, and a single pulse reduction in temperature of 1°C at day 6) compared with birds that were produced from using an 'ideal' incubation profile. However, a study by Shim and Pesti (2011) that manipulated incubation temperature reported no effect on the incidence of leg bone abnormalities in control birds, or in broilers experimentally induced to develop TD or phosphorous-deficient rickets.

Femoral head necrosis (FHN) is currently the most prevalent and widespread endochondral bone growth problem within Europe, although the pathology is being successfully addressed with improved hatchery hygiene (Whitehead, 2010). Tibial dyschondroplasia (TD) is less prevalent than in recent years due to selective breeding programmes and can be effectively prevented by dietary supplementation with 25-hydroxyvitamin D (Whitehead, 2010) . Rickets is currently only an

occasional problem, occurring due to malabsorption of dietary nutrients (e.g. calcium, phosphorus, or vitamin D) or, more usually, from dietary errors (Whitehead, 2010). However, although in decline, it is thought that permanent skeletal deformities that arise as a consequence of rickets experienced at the beginning of the growth cycle may increase the likelihood of a flock developing additional pathological states (FHN, osteomyelitis, fractures, TD, spondylolisthesis) during the finisher period (Dinev and Kanakov, 2011).

Diet is an important factor in determining bone strength. Oso et al. (2011) provide evidence against the use of wood ash as a non-phytate calcium source in broiler feed as it has been linked with a significantly higher prevalence of lameness than alternatives including oyster shell, snail shell, and limestone. Early-age water restriction has been discounted as an alternative to feed restriction for improving leg health in male broilers (Toghyani et al., 2011).

The relationship between gait score and leg abnormalities and pathologies remains complex. Gait scoring (GS) is relatively quick and easy to do and it is for this reason that it has been used extensively when assessing leg health in commercial flocks (e.g. in the Welfare Quality® assessment protocol for broilers (Welfare Quality, 2009)). However, GS cannot discriminate between, for example, birds that have poor gait because of an underlying painful pathology and birds that have poor gait due to their conformation but may not be experiencing pain. A study by Sandilands et al. (2011) revealed that neither gait scoring nor force-plate assessment could accurately predict leg health in individual birds as observed post-mortem. This suggests that kinetic techniques are unsuited to detect pathology prevalence at farm level. However, automated image monitoring systems show promise for monitoring broiler activity at farm level. Aydin et al. (2010) describes a system with potential for remotely assessing gait score, and therefore leg health, while Kristensen and Cornou (2011) report the use of digital motion detection to detect abnormal deviations in activity level. The incorporation of these technologies within automated monitoring systems could be used to alert producers when flock activity levels fall below an accepted level and therefore forewarn them of the development of muscular-skeletal problems within a flock.

In a study based upon previous findings, that light colour, source, and intensity can affect broiler activity, Sherlock et al. (2010) investigated the use of step changes in light intensity (10 and 200 lx) during an 18h L: 6h D photoperiod to increase broiler activity (and thus leg health) compared to control conditions (10 lx). Both activity levels and leg health were unaffected by stepped lighting, and activity was unrelated to gait score and bone strength. The absence of a correlation between activity and bone strength (cortical density) contradicts an earlier study that observed increased activity to improve walking ability (Reiter and Bessei, 1995, as cited within (Sherlock et al., 2010) . These findings imply that husbandry measures other than stepped lighting are needed to produce greater increases in activity levels and thus improve leg health. A further study on lighting regimes (short cycle versus uninterrupted (18h and 23h) (Lewis et al., 2010) also failed to observe an effect upon tibial bone strength. A study utilising the Welfare Quality® broiler welfare assessment protocol identified length of dark period (at 21 days of age assessment) as being a risk factor for poor welfare in commercial broiler flocks (Bassler, 2011). Flocks with a dark period of >4h/d had approximately 12% fewer birds at GS>2 than flocks with a dark period <4h/d.

Stojcic and Bessei (2009) studied the effects of increased and reduced weight load on leg disorders in fast and slow growing chickens. They found for the fast growing chickens that low locomotor activity was the direct reason for leg disorders. Decreased weight load increased locomotor activity and reduced leg disorders in fast growing broilers. In contrast, bones and joints of slow growing broilers were so robust that an increase in weight load resulting in reduced locomotor activity did not result in any bone and joint deteriorations.

In a large study applying the Welfare Quality® broiler assessment protocol in Dutch (majority of the flocks), British, Belgian and Italian flocks, on average 57% of the birds in flocks with standard, fast growing strains had a gait score≥3 and on average 17% of the birds in flocks with alternative, slower growing strains had a gait score ≥ 3 (De Jong et al., 2011a).

In commercial flocks, the most lame birds (gait score 4 and 5) often are less than the average flock weight due to retardation in growth and weight gain (Butterworth, personal communication).

2.1.2.1. Conclusions

Additional conclusion:

1. There are some indications that incubation conditions may affect leg health, but further research is necessary.

2. Gait score is widely used to assess broiler leg health in commercial flocks. However, gait score cannot discriminate between underlying pathology or poor gait due to conformation.

2.1.3. Muscle disorders

A low prevalence (0.51%) of deep pectoral myopathy within intensively reared Bulgarian flocks has been reported (Dinev and Kanakov, 2011).

2.1.4. Contact dermatitis

2.1.4.1. Hock burns

In a recent on-farm study in the UK, Hepworth et al. (2011) found an average prevalence of hock burns of 12%. They also found that the incidence of hock burns was associated with other measures of flock health, such as the percentage of septicaemia, dermatitis, runts and fever, indicating that incidence of hock burns may be a useful indicator of flock health. Hepworth et al. (2010) also showed that weight and weight density at two weeks of age may be useful indicators of flocks at risk of a developing a high incidence of hock burns. In contrast, they found that stocking density at placement was not a good predictor.

In another study, hock lesions were measured at 30 UK farms. Prevalence varied by season, with increased hock lesion prevalence in autumn (mean 54% compared to 7% in spring measured at slaughter age). From this project (including also studies in an experimental setting) evidence accumulated for aetiological differences between foot and hock lesions: hock lesions are generally seen later than foot lesions (when birds are larger, and more inactive); hock lesion development is strongly related to gender (and weight); and hock lesions appear to be less directly related to litter characteristics than foot lesions, especially under commercial conditions. However, both foot and hock lesions were induced on wet litter and to a greater extent at high ammonia concentrations. Based on the available evidence it is reasonable to speculate that physical factors associated with pressure sore formation such as tissue loading, shear and friction forces are an influence in hock lesion development. It is known that lesions which originate in this way can be exacerbated by external irritants including moisture, so it is likely that both environmental and physical factors work synergistically to promote lesion development (McKeegan, 2010).

In a study applying the Welfare Quality® assessment protocol for broilers in 114 Dutch, British, Belgian and Italian flocks assessed at slaughter prevalence of hock burns was about 20% in standard, fast growing broilers and less than 1% in alternative, slower growing broilers (Welfare Quality, 2009).

2.1.4.2. Foot-pad dermatitis

Hashimoto et al. (2011) reported the incidence of foot-pad dermatitis (FPD) in 45 commercial Japanese broiler flocks. In 3 flocks, all the birds examined had lesions. In the other 42 flocks, the incidence of FPD ranged from 31.9% to 99.5%. They confirmed previously found results that incidence was higher in males than in females and higher in winter than in summer. There was no difference between flocks from windowless houses and open-sided houses. In a Brazilian study on commercial flocks (Xavier et al., 2010), effects of litter type on foot-pad dermatitis were found, as has also been reported in previous studies. They found incidences of foot-pad dermatitis of 53% on corn cob litter, 45% on grass litter, 33% on sawdust and 19% on rice shell litter. Interestingly, they also found that the incidence of foot-pad dermatitis decreased in most cases if the same litter was reused in subsequent batches of birds, using five batches in total. A similar study was performed by Bilgili et al. (2009), comparing eight different bedding sources. They also found that incidence of foot-pad dermatitis varied considerably among bedding materials. The incidence of foot-pad dermatitis was correlated with high litter moisture and high caking scores. Chipped pine, chopped straw, cotton-gin trash, and pine shavings showing the highest severity scores and mortar sand and ground door filler (a wood fiber-based material used in insulating metal doors) showing the lowest. The authors suggest that the ability of the bedding to absorb (i.e., ground door filler) and quickly release (i.e., mortar sand) moisture may be the most important characteristics of litter in preventing foot-pad dermatitis. Cengiz et al. (2011) observed that experimentally increasing the moisture content of litter significantly increased the incidence of FPD in 14 d old broilers, but this effect was not observed in birds older than 56 d. Smaller litter particle size and increased litter quality was associated with a reduction in FPD. This suggests that although younger birds are more susceptible than older birds to developing FPD when housed on inappropriate litter, lesion severity can be improved in market-age broilers following subsequent improvements in litter quality.

FPD was measured over the course of one year in Dutch flocks with standard, fast growing broilers. On average 35.5% of the broilers had no lesions, 26.1% had mild FPD and 38.4 % had severe lesions. Season, age, thinning of flocks and slaughter age, breed, slaughterhouse and the interaction between thinning and slaughter age significantly affected FPD levels. FPD levels were higher in cold and wet seasons as in summer. Generally, birds sent to slaughter when thinning a flock displayed less severe FPD than birds from completely depopulated flocks. Additionally, the severity of FPD decreased with age. Since poultry farmer, hatchery, veterinary service and feed manufacturer were included in the model as random factors it was only possible to assess their contribution relative to each other. The relative contribution of poultry farmer was the largest. A relatively large contribution was also found for hatchery, perhaps indicating that broiler quality plays a role. No relationship was observed between FPD and mortality. Across farms fewer lesions were observed on farms using antibiotics. However, within farms FPD was higher in flocks where antibiotics had been used compared to flocks that did not require such treatment (De Jong et al., 2011c). In a study applying the Welfare Quality® assessment protocol for broilers in 114 Dutch, British, Belgian and Italian flocks assessed at slaughter, the prevalence of FPD was about 22% in standard, fast growing broilers and around 7% in alternative, slower growing broilers (Welfare Quality®, 2009).

In a study on 30 UK commercial farms, FPD levels varied between 35 and 65% depending on the season. A series of findings throughout the project supported the idea that litter moisture content and in particular resulting ammonia concentration is the key causal factor in foot lesion development. Management approaches to reducing these conditions should concentrate on minimising moisture accumulation in litter, particularly in the early rearing period when the birds appear to be more susceptible to lesion development. Results supporting the notion that the lesions are associated with reluctance to walk (possibly as a result of pain) help to identify the lesions as a welfare issue (McKeegan, 2010). In a study at potential risk factors for poor welfare it was found that with decreasing litter quality (as scored in the Welfare Quality® assessment protocol for broilers) the

number of birds with moderate or severe FPD increased with 12.9% per litter scoring unit (Bassler, 2011).

Ventura et al. (2010) observed a positive linear relationship between foot-pad and hock lesion severity and housing density. The same study also revealed a trend for reduced footpad lesion severity following provision of simple barrier perches, although this same treatment had no effect on hock lesions.

An effect of stocking density was also found by Buijs et al. (2009), who observed an increase of 1 to 3% moving from a stocking density of 6 kg/m^2 to 56 kg/m^2.

When intensively housed broilers were raised to 35d using one of four light intensities (1, 10, 20, and 40 lx) (Deep et al., 2010) observed ulcerative footpad lesions to decrease linearly with increasing light intensity.

Balanced genetic selection for both body mass and FPD in contrasting environments can be an effective strategy to reduce the genetic disposition to develop FPD in broilers (Kapell, 2011).

Since presence and severity of foot-pad lesions are widely used as a welfare indicator it is necessary to utilise a reliable sampling methodology on farm. De Jong et al. (2011d) observed a significant effect of sampling location indicating that severity of foot-pad lesions were unevenly distributed over the house within their sample flocks. To achieve accuracy they recommend that at least 100 birds per commercial broiler house are sampled, spread over as many locations as possible. This is in agreement with the Welfare Quality® assessment protocol for broilers. Measuring FPD at slaughter has several advantages as compared to measuring on-farm: the assessment does not cause stress to the birds as FPD is assessed at the plant after killing; as the feet have passed the scalding tank most of the litter and manure is removed, in contrast to rather dirty feet in commercial broiler houses; scoring at the slaughter line is more time efficient as compared to scoring on-farm; samples can easily be stored if necessary (De Jong et al., submitted). An automated method for assessment of FPD at slaughter has been developed, using video-imaging to score the lesions. This method is now ready to be implemented in practice (De Jong et al., 2011b).

A review by Shepherd and Fairchild (2010) underlined the importance of preventing foot-pad dermatitis, not only from a welfare perspective, but also from an economical perspective: chicken paws are becoming more important in the global poultry markets. In 2008 alone, revenue from chicken paws was worth $280 million. For this market, it is of course very important that the chicken paws are unblemished by contact dermatitis.

2.1.4.3. Conclusions

New conclusions:

1. Because of the relationship with management factors, flock health and the fact that foot and hock lesions are likely to be painful, FPD and hock burns are useful welfare indicators in broilers.

2. Hock and foot lesions likely have a partially different aetiology, where hock lesions are not only related to wet litter and ammonia concentrations in the litter (like FPD) but also to the weight of the birds.

2.1.5. Ascites, pericarditis, sudden death syndrome and spiking mortality syndrome

2.1.5.1. Ascites

Risk factors

It has been shown that heart condition is an important risk factor for mortality during catching and transport of broilers. The pathological condition of broilers that were dead on arrival (DOA) at the slaughterhouse were compared with that of slaughtered broilers (Nijdam et al., 2006). Forty-two percent of the DOA birds died because of heart and circulation failures and 34% had an enlarged right heart ventricle, compared with 3% in standard birds. The DOA broilers with an abnormal heart ratio had a high incidence of ascites and hydropericardium. A decrease in the prevalence of ascites would, therefore, have substantial potential for reducing the DOA rate.

A recent study by Ozkan et al. (2010) confirmed some of the risk factors for ascites identified in previous studies: they investigated effects of altitude, ambient temperature, feed restriction and sex and found a higher incidence of ascites at high altitude and at low ambient temperatures. Furthermore, mortality was higher in males than in females. Feed restriction helped to reduce ascites in the high altitude treatment, especially in males (44% versus 26% ascites in ad lib and restricted males), but maintaining a high ambient temperature was the most successful remedy (13% ascites). If feed restriction is applied, feed restriction from day 7 to 14 is advisable. Prolonging feed restriction to day 21 did not improve mortality rates and negatively affected performance.

Nutrition

It was demonstrated that a feed restriction regime whereby broilers only had feed available for 8h per day led to lower body weight gain, lower right/total ventricular weight ratio, lower general mortality and lower death due to ascites compared to an ad libitum-fed control group of broilers, but had no significant effect on growth performance (Boostani et al., 2010).

To reduce ascites in broilers higher levels of dietary vitamin C and E along with selenium might be beneficial, as they decrease the free radicals that are generated in birds with ascites (Gupta, 2011). Feed composition can also influence the incidence of ascites. Khajali et al. (2011b) showed that diets based on canola meal led to a higher incidence of ascites than diets based on soybean meal (16 versus 11% mortality). This could, however, be compensated by supplying extra arginine (0.4%) in the diet, resulting in similar mortality levels as the soybean meal diet. This protective effect of arginine against ascites has also been found by Tisljar et al. (2011), who used injections with arginine in their experiment. Further, Bautista-Ortega and Ruiz-Feria (2010) were able to confirm the positive effects of arginine and anti-oxidative vitamins E and C supplementation on cardiovascular performance in broilers. Rajani (2011) also found that supplementation of diets with antioxidant feed additives improved right/total ventricular weight ratio and reduced mortality in broilers with experimentally-induced ascites compared to a control group. In diets containing vegetal fat, the addition of sodium salt was found to have positive effects on prevention of ascites (Kalmar et al., 2011). Khajali et al. (2011a) showed that ascites may be caused by increased levels of methylglyoxal. Methylglyoxal is a dicarbonyl molecule that forms during glycolysis and normally is detoxified via the glyoxalase system. This study showed that intravenous and intramuscular Methylgyoxal injections triggered pulmonary hypertension.

Brooding

Molenaar et al. (2011) showed that a high eggshell temperature (EST) of 38.9°C from day 7 of incubation resulted in 26% lower heart weights at hatching and a lower body weight during the growing period compared with a normal EST of 37.8°C. Further, a high EST led to a 4% increase of

mortality and a 4% increase in ascites compared with a normal EST. Shinder et al. (2011) found that cold resistance in broilers can be induced by applying cold stress (exposure to brief periods of 15°C) during brooding, reducing the incidence of ascites from 70 to 44% and mortality from 52 to 33% under low temperature conditions. This indicates that the brooding process has significant effects on the incidence of ascites post-hatching.

Genetic selection

Genetic selection may also offer opportunities to reduce the incidence of ascites (Pakdel et al., 2005). Quantitative Trait Loci's (QTLs) were detected controlling an ascites indicator trait (the ratio of the weight of the right ventricle as a percentage of the total ventricle weight) across the whole genome (Closter, 2010). They also found QTLs that were significant for both the indicator trait and body mass, suggesting that there is an association between the development of ascites and body weight. While Elferink (2011) recently discovered 18 QTLs (genetic regions) and 10 genes that are involved in ascites. Further, he identified a large number of Single Nucleotide Polymorphisms (SNP's) that could be used as genetic markers in future genetic association studies. (van As et al., 2010) showed that CO_2 pressure and pH in venous blood, measured at day 11 and 12 of life, can be used as predictors of ascites. They found that high CO_2 pressure values together with low pH values (males) or high pH values (females) in the venous blood of juvenile broilers coincided with ascites (van As et al., 2010). High CO_2 pressure values were also associated with ascites in a study by (Hassanzadeh et al., 2010), comparing fast and slow growing broilers. These phenotypic traits could be used in genetic selection against ascites.

2.1.5.2. Sudden death syndrome

Photoperiod may affect the incidence of sudden death syndrome (SDS). Mortality has been observed to increase proportionately with increasing day length at photoperiods above 12 h. As day length was increased over the range 2 to 10 h deaths due to SDS decreased, but as day length was further extended to 24 h incidence of SDS increased (Lewis et al., 2009).

2.1.5.3. Conclusions

New conclusions:
1. Diet composition may affect the incidence of ascites.

2. The brooding process may affect the incidence of ascites post-hatching.

Amended conclusion:
1. Low energy intake can decrease SDS and ascites because of a slower growth rate.

2.1.6.   Respiratory and mucous membrane diseases

The effects of atmospheric ammonia on the respiratory system have been reviewed by Aziz and Barnes (2010). The effect of ammonia gas on the mucosal surface of the trachea ranges from paralysis of cilia, to deciliation (loss of cilia) of epithelial cells, to injury (necrosis) of the mucosal epithelium itself. Attenuation of the mucosal epithelium, with loss of cilia and increased numbers of goblet cells, are common lesions of aerial ammonia toxicity seen in the tracheas of affected birds. The type and degree of damage depends on the concentration of ammonia in the air and the length of time of exposure. Damage to the respiratory system due to high ammonia concentrations may be cause air sacculitis, pneumonia and septicaemia caused by E. coli (Aziz and Barnes, 2010). Prolonged exposure to atmospheric ammonia may also incite proliferation of the epithelial cells that line the atrial spaces in the lung. The proliferative lesion causes thickening of parabronchial walls. In severe cases, total obliteration of atrial spaces, with subsequent reduction in pulmonary gas exchange can occur (Aziz and Barnes, 2010).

2.1.6.1. Conclusions

No new or amended conclusions.

2.1.7. Thermal discomfort

Genetics

Heat stress in broilers impairs performance, induces intestinal injury and decreases macrophage activity, thereby reducing immune responsiveness (Quinteiro-Filho et al., 2010). Li et al. (2011) showed that heat stress in broilers results in changes in gene expression. They found that 110 genes changed in gene expression after three weeks of heat stress, revealing genetic pathways involved in heat tolerance. Soleimani et al. (2011) compared heat tolerance in Red Junglefowl, village fowl and commercial broilers and showed that broilers had a much greater heat tolerance than the other two breeds. This is probably the result of intense genetic selection in commercial broilers. The naked-neck genotype seems to be more heat resistant than the normal feathered genotype (Rajkumar et al., 2011). Azad et al. (2010) compared the effects of heat stress on performance of White Leghorn chickens and commercial broilers and found that the broilers were more severely affected by heat stress, with regard to growth depression, than the layers.

Brooding

Halle and Tzschentke (2011) showed that brooding temperature also affects the ability of the animal to cope with heat stress later in life, especially in male broilers. Chronic, warm incubation leads to lower growth and reduced problems with heat stress in male broilers. In male chickens chronic warm-incubation (38.2-38.4°C) from day 18 until hatch lead to a lowered daily feed intake in the final growing period (and low final weight). This depressed feed intake would decrease bodily heat production and could help to minimize heat stress. In addition Aksit et al. (2010) observed that when eggs were heat acclimatised (incubated at 39.5°C for 6 h daily from d 10 to d 18) and these chicks were kept at a high brooding temperature of 35°C they had lower H:L ratios than 'control' chicks incubated at 37.5°C. Lower H:L ratios also suggest that heat acclimatised birds may cope better with heat stress.

Dietary strategies

Growth depression as a result of chronic heat stress in broilers may be reduced by dietary supplementation with methionine (Bunchasak, 2009; Willemsen et al., 2011), which appears to reduce oxidative stress. Similar positive effects on heat-stressed poultry have been described for vitamin E (Niu et al., 2009; Khan et al., 2011), minerals such as Zinc (Sahin et al., 2009), glutamine and gamma-aminobutyric acid (Dai et al., 2011) mannan-oligosaccharides and probiotic mixtures (Sohail et al., 2011). Mujahid (2011) recently concluded that a combination of the nutritional supplements may help to alleviate the deleterious effects of heat stress and maintain efficient chicken production under high environmental temperatures. The electrolyte balance in the diet may be very important in allowing broilers to cope with heat stress (Ahmad et al., 2009).

Transport

Heat and cold stress can occur during transport to the slaughterhouse. Knezacek et al. (2010) showed that cold stress may occur near the air inlets of the truck and heat stress in poorly ventilated areas of the truck. Negative effects of heat stress during transport could be reduced by administration of vitamins E and C prior to transport (Minka and Ayo, 2010).

2.1.7.1. Conclusions

New conclusion:

1. Brooding conditions may affect the ability of the animal to cope with heat stress later in life.

2.1.8. Behavioural restriction

See 1.4.9. for updated information.

2.1.9. Environmental factors linked to welfare

See 1.5. for updated information.

2.1.10. Nutrition and feed management, water

See 1.6. for updated information.

2.1.11. Digestive function

Mixing of whole wheat in with standard pelleted broiler feeds gives as good performance as could be achieved by feeding the pellets alone. The reason for the good performance under these conditions is not fully understood, but may be related to better overall digestion resulting from longer retention of feed in the gizzard and the presence of endogenous enzymes that would normally be destroyed during the heating of wheat (Hetland et al., 2002). In addition, whole wheat feeding seems to improve gut health by stimulating gizzard function. With higher hydrochloric acid secretion and lower pH, the gizzard can be regarded as a barrier organ in the prevention of pathogenic bacteria entering the distal intestinal tract (Engberg et al., 2004).

Mignon-Grasteau (2010) estimated that heritability for digestibility, measured as Apparent Metabolisable Energy corrected to zero nitrogen retention (AMP_N), was 0.32 when fed on wheat while h^2 was 0.15 when fed on corn. The conclusions of their work including (Mignon-Grasteau et al., 2004) are that the selection for higher growth should take place on a diet that contains wheat if the broiler has to grow on wheat. Further, if selection also includes AME_N one will improve the feed efficiency and reduce the risk of poor litter quality.

2.1.11.1. Conclusions

1. Suboptimal digestibility of feed may have a negative effect on litter quality and in this way affect cleanliness of the birds and the incidence of contact dermatitis.

2.2. Indicators used in practice

No new information.

2.3. Genetic selection of broilers

2.3.1. Production traits

No new information available.

2.3.2. Health, fitness and welfare traits

DNA technology with high density markers may also be useful for implementing a Gene or Marker Assisted Selection on welfare related traits. Thus, significant associations between markers from a SNP chip and ascites were recently reported (Closter, 2010) while the same approach led to the identification of a candidate gene and of candidate mutations involved in the control of bone traits

(Zhang, 2011). For both kinds of traits, significant association with body weight was also reported showing the input of the molecular data not only for selection but also for a better understanding of the causative mechanisms linking welfare and production traits.

As underlined by Beaumont and Chapuis (2004), selection on welfare-related traits has to deal with a number of methodological difficulties: (a) because of the large dependence of these traits on environment, it is necessary to anticipate the future conditions of rearing to choose the most appropriate conditions of measure; (b) statistical questions arise as the measurements may not be normally distributed or are censured; (c) the direction of selection is for an optimal level should be considered; (d) as welfare cannot be summarized by one trait, such a selection implies that selection for several traits will be necessary; (e) the need for long and time-consuming measures is a major issue for practical application of selection for improved welfare. The latter could be changed by the development of automatic recording, image analyses and the replacement of individual measurements by genomic markers (i.e. genomic selection).

2.3.3. Reproduction traits

Genetic correlations between reproduction and production traits are antagonistic suggesting that selection solely for production traits may adversely affect reproduction. As before, genetic correlation means that the same genes or genes located very close to each other influence both reproduction and production traits. Common loci for body weight and sexual maturity have been identified which indeed suggested that the genetic determinism of growth rate has correlated responses on puberty (Podisi et al., 2011).

2.3.4. Trait combination – selection indices

No new information available.

2.3.5. Genetic selection by production system

No new information available.

2.3.6. Policies of breeding companies regarding selection for welfare versus production

Even if they are market and price dependent, the percentage of improvement in profit of an integrated broiler operation has been estimated at 0.23 for 1% improvement of egg production of the breeders, 0.46 for the hatchability in the hatchery, 0.32 for broiler weight, 0.42 for broiler mortality, 1.31 for feed conversion, 3.10 for breast meat percentage (Emmerson et al. 2003 cited by (Decuypere et al., 2010)). This explains why more emphasis has been put on the production traits of broilers rather than on the reproductive traits of breeders, the latter being mainly improved by dedicated programmes of food restriction. In the same time there are more and more data in the literature showing that fast and efficient growth of the broilers and efficient reproduction of the breeders are mutually exclusive breeding goals, suggesting a causal negative biological link (Decuypere et al., 2010). Knowing these biological and genetic data, a decreasing selection pressure for productive traits concomitantly with an increasing selection pressure for non-productive traits (such as welfare traits) in broilers could be the way to reach acceptable productivity of the broilers together with acceptable management systems of the breeders.

One of the leading breeding companies claims, in a paper entitled 'Striking a balance between economic and well-being traits', that more than 50% of the 56 traits they record on each pedigree candidate are measures of health and fitness (Katanbaf and Hardiman, 2010). As the statement is not followed by information on the weight that these health and fitness traits participate with in the breeding index it is not possible to use that to give any explanation of how much weight they actually put on health and fitness.

Conington et al. (2011) concluded that use of a broader breeding goal could only be realised if robust phenotypes are available to distinguish between animals in their ability to resist disease, ability to express desirable behaviour or better to adapt to changing management. Using such a breeding program with considerable weightings on non-production traits, will tip the balance in favour of fitter and healthier animals that will be more productive and economic, not through higher production but through less mortality and morbidity and through easier management.

Another approach to improved welfare and health could be through a demand driven solution in which consumer groups or high end supermarkets demand a higher standard of welfare, health and behaviour be made available through breeding programs. This of course will be followed through a higher price as e.g. is the case for organically produced products. Whichever way animal breeding develops in the future, it is a paramount that breeding for resistance to disease, or for animals to adapt better to poor environments, does not discourage the development of higher standards of stockmanship and good quality of the environment (Conington et al., 2011).

2.4. Genotype by environment interaction

2.4.1. Welfare aspect of interaction between genotype and environment

No new information available.

2.4.2. How do the breeding companies deal with GxE interaction?

No new information available.

2.4.3. Importance of the genetic diversity

No new information available.

3. Welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes - Sub-report C

This part updates the underlying report: Scientific opinion on welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes (2010, available at http://www.efsa.europa.eu/en/efsajournal/pub/1667.htm).

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In general, the content of the report is based only on new available information since the editing of the original report (EFSA, 2010).

3.1. Housing and management of broiler breeders (parents and grandparents)

Since the original report (EFSA, 2010) there has been only a few changes in the housing and management of broiler breeders. These are listed below under the appropriate heading. Where no information is provided, no new information was available with respect to housing and management.

3.1.1. Mutilations

In The Netherlands, the ban on mutilations in poultry has been postponed until 2021. From 2011 onwards beak trimming of poultry in The Netherlands shall be carried out using infrared technology, except in chickens from young grand-parent stock (with a maximum age of 31 weeks) or imported chickens that arrive with intact beaks. In these groups beak trimming may be carried out at the farm until 10 days of age.

3.1.1.1. Conclusions

No new or amended conclusions.

3.2. Overview of the welfare of broiler breeders

3.2.1. Feed restriction

Current research is assessing the effects of feed restriction on the subjective experiences of broiler breeders, using behavioural and neurophysiological techniques. To date, conditioned place preference and aversion methods (which test birds in the absence of food) indicate that broiler breeders prefer the environment associated with greater food rations, indicating a better subjective state experienced in that environment. Levels of AGRP mRNA, the product of which acts to block the anorectic action of alpha-MSH at the MC4 receptor, showed an approximate 58 fold increase in restricted fed broiler breeders compared to ad-libitum fed birds, indicating that feed-restricted birds may be experiencing greater appetite than birds fed to satiation (D'Eath et al., 2010).

In a study to test the relationship between feeding motivation and the incidence of floor eggs in broiler breeder hens it was shown that the motivation to eat a limited allocation of feed during production, where the restriction level is much lower compared to the rearing phase, was still very high. Hens fed the commercial diet abandoned the sitting phase of pre-laying behaviour (an important aspect of nesting behaviour) when the feed was provided during nesting (Sheppard and Duncan, 2011).

Alternative feeding strategies may be useful to reduce the negative effects of feed restriction on broiler breeder welfare while maintaining the desired growth rate. In contrast to earlier research (see EFSA (2010 for an overview), a recent study has shown that scatter feeding using high fibre diets may alleviate the sensation of hunger of broiler breeders during rearing. Induced behavioural signs of welfare by the use of scattered high insoluble fibre feed included; increased foraging, dust bathing and comfort behaviours, while reducing negative behaviours such as tail pecking and stereotypic pecking. On the contrary, birds fed a diet with a high proportion of soluble fibre showed behavioural signs of discomfort. It was concluded that a high ratio of insoluble fibre in the diet of broiler breeders in rearing may alleviate feelings of hunger and improve the welfare of the birds (Nielsen et al., 2011). It should be noticed however, that the costs of high fibre diets (increased manure, ingredients, transport costs) are high.

3.2.1.1. Conclusions

Additional conclusion:

1. The use of diets with a high proportion of insoluble fibre may alleviate sensation of hunger during rearing.

3.2.2.   Aggression

3.2.2.1. Mating behaviour and aggression

A study was carried out to determine the relationship between mating frequency and the degree of feathering on the back of the hens. The assumption was that less feathering on the back resulted from more frequent matings. Results showed that the hen strain with greater feather loss had fewer mounts by males as well as fewer completed matings, indicating that feather loss is not necessarily caused by increased mating activity and, in fact, may deter such behaviour. There was a trend for more male aggression towards females of the strain with less feathering on the back, which appeared to be induced by frustration due to sexual rejection by the hens, or the increased aggression may have been an attempt at intimidating the hens into mating (Moyle et al., 2010).

Mating behaviour is affected by stocking density of broiler breeders, particularly during production. Broiler breeders were housed at a standard stocking density, or half the stocking density in rearing and/or production. The density treatments were: (1) low stocking density during rearing and production phases, (2) standard stocking density in rearing and production, (3) low stocking density in rearing, standard stocking density in production and (4) standard stocking density in rearing, low stocking density in production. Stocking densities were 14.5 vs. 7.25 hens/m^2 in rearing, 11.0 vs. 5.5 males/m^2 in rearing, and 8.0 birds/m^2 (10% males) versus 4.75 birds/m^2 (10% males) in production. Mating behaviour of males and females was improved by a low stocking density in production: higher frequencies of completed matings and courtship behaviour preceding matings, as well as fewer forced matings, and less struggling of the hens were observed at the low density. Stocking density during rearing had only a minor effect on mating behaviour in production. Less feather damage in the hens at low stocking density was found during the production period, which was probably caused by the more appropriate mating behaviour of males and females at the low stocking density (De Jong et al., 2011).

In a study of the potential causes of rupture of the gastrocnemius tendon in broiler breeders it was suggested that the non-infectious cause of the rupture is aggression due to the introduction of new males in a flock ('spiking') (Crespo and Shivaprasad, 2011).

3.2.2.2.   Conclusions

Amended conclusion:

1.   Improved management protocols (such as reducing stocking density or use of environmental enrichment) can be used to improve mating behaviour, reducing the frequency of force matings.

3.2.3.   Mutilations

3.2.3.1.   Beak trimming or partial amputation of the beak

No new studies are available for grandparent or parent stock of broiler breeders. However, a recent study in pullets of a laying strain compared the effects of hot blade and infrared beak trimming, applied the day of hatching, in beak topography and growth until ten weeks of age. For the most part of the study, feed intake and feed waste was higher in the control birds, intermediate in the birds with infrared beak trimming and lowest in the birds with hot blade beak trimming. Similar differences were found for body weight. Beak regrowth was most profound in hot blade beak trimmed birds. It was concluded that although both beak trimming methods affected production parameters, infrared beak trimmed birds performed better and had less beak re-growth as compared to the hot blade beak trimmed birds (Marchant-Forde and Cheng, 2010). It can be assumed that these results would be valid also for broiler breeders.

Changes in pecking behaviour after beak trimming has previously been interpreted as being indicative of pain. In a recent study, it was shown that hot-blade beak trimming at the day of hatching in laying-strain chicks did not result in pain (measured until 9 days of age). Instead, beak trimming led to impaired function of the magnetoreceptors and mechanoreceptors of the beak (Freire et al., 2011).

3.2.3.2. Other mutilations

Comb dubbing is no longer a standard procedure in broiler breeders and it was estimated that comb dubbing is carried out in less than 10% of the broiler breeder males upon customer request, using scissors at the hatchery (EFSA, 2010). In a pilot study, the effects of comb dubbing on growth, feed intake, mortality and behaviour in male layer chicks was studied until the end of the experiment at 14 days of age. No differences in these parameters were found between dubbed and non-dubbed males. It was concluded that the results indicate that dubbing did not cause severe discomfort, but it could not be concluded that dubbing causes no discomfort as no long-term measures were carried out and no physiological indicators of stress were measured (Van Niekerk et al., 2011).

3.2.3.3. Conclusions
1. Infrared trimming likely offers welfare and performance advantages over hot-blade trimming (according to studies in laying-strains).

3.2.4. Environmental enrichment

No new information available.

3.2.5. Ammonia and dust

No new information available.

3.2.6. Light

No new information available.

3.2.7. Stocking density

The effects of stocking density on mating behaviour are discussed under 3.2.2. Reducing the stocking density of broiler breeders during the rearing phase (14.5 hens or 8.0 males/m^2 (standard) versus 7.25 hens or 5.5 males/m^2 (low)) had a small but significant effect on their behaviour. More foraging and less standing was observed in females, while males showed more walking at low as compared to standard stocking density. Aggressive interactions were studied during rearing at 3, 6, 9 and 12 weeks of age. No effects of stocking density were found on female aggressive behaviour. Higher frequency of aggressive interactions were observed in males at a lower density, probably related to the larger space availability. Nevertheless, feather and skin damage was comparatively less in both males and females at the low stocking density, therefore suggesting that increased male aggression observed at low density had no major welfare consequences (De Jong et al., 2011).

The effects of stocking density on injuries and technical parameters during the production phase were also studied. Decreasing stocking density of broiler breeders during the production phase improved their technical performance as well as feathering condition. Hens at low stocking density in production had improved fertility and hatchability, while both males and females had significantly better plumage condition at the end of the rearing and the end of the production period (De Jong et al., 2011).

3.2.7.1. Conclusions

New conclusion:

1. Reduction of stocking density may reduce feather damage and have positive effects on behaviour and hen performance

3.2.8. Contact dermatitis

No new information available.

3.2.9. Culling

No new information available.

3.2.10. Transport and slaughter

No new information available.

3.2.11. Cage housing

No new information available.

3.2.12. Leg weakness

No new information available.

3.2.13. Peritonitis and salpingitis

No new information available.

3.2.14. Metabolic disorders

No new information available.

3.2.15. Infectious diseases

No new information available.

3.2.16. Biosecurity measures, management and organization

No new information available.

3.2.17. Control option for airborne transmission of infectious agents from farms

No new information available.

3.2.18. Training of stockpersons

No new information available.

3.3. Indicators used in practice

No new information available.

CONCLUSIONS AND RECOMMENDATIONS

PROPOSED POSSIBLE AMENDMENTS TO THE CONCLUSIONS TO THE PREVIOUS SCAHAW REPORT (2000)

Welfare: definitions and measurements

1. For an adequate assessment of welfare a wide range of indicators must be used, although single indicators can show that welfare is poor. Animal welfare can be assessed in a scientific way and indicators of welfare include those of physiological states, behaviour and health.

2. The Welfare Quality® assessment protocol for broilers proposes a set of animal-based and resource based measures to assess broiler welfare under commercial conditions.

Biology of fowl/broiler:

1. Broilers have an intrinsic motivation for certain behaviours, however their physical ability may prevent them from performing some behaviours in accordance with their motivation, and this may affect their welfare negatively.

Behavioural restriction:

1. High stocking densities disturb locomotor behaviour and rest, both of which have an influence on leg health in broilers although the nature of this impact is not clear.

2. Selection for increased growth impedes the activity level of broilers.

3. Enrichment strategies may alleviate behavioural restriction of broilers by increasing locomotion and preventing disturbance of rest.

Air quality:

1. Air quality in a broiler house is determined by a complex interaction between many factors including ventilation, stocking rate, litter quality, age and health status of the birds. The EU Broiler Directive (Commission, 2007) advises 20 ppm for ammonia, 3,000 ppm for carbon dioxide and 70% for humidity as upper limits.

2. Air humidity largely depends on appropriate function of the ventilation and drinker system, but is also dependent on outside humidity. When levels increase to more than 70% under high temperature, serious welfare problems occur, and animals may die. Relative humidity below 50% leads to an increase in airborne particulate matter and increasing susceptibility to respiratory diseases.

3. Levels of CO_2 of 1% do not, by itself, cause any harm for animals. However, an increase in CO_2 levels is usually accompanied by increased levels of other detrimental air pollutants such as ammonia, dust and micro-organisms. Therefore CO_2 is used as an air quality indicator.

4. High concentrations of ammonia are regularly observed in commercial broiler houses. The harmful effects result from a combination of high concentration and exposure time. Concentrations over 10 ppm increase the susceptibility for respiratory diseases.

5. N_2O and CH_4 do not occur in broiler houses in concentrations which may influence health or welfare of animals. Other gases, such as CO and H_2S, are potential risk factors for broiler

welfare, but there are little data available on commonly occurring concentrations or on risk levels.

6. Dust is a potentially harmful air contaminant, mainly in combination with ammonia and other gases and may directly affect the respiratory tracts of the broilers, as well as act in the transmission of bacterial and viral infections. Dust levels can be kept to a minimum by appropriate ventilation and by maintaining recommended humidity levels.

Litter Quality:

1. Maintaining a good litter quality is essential for broiler health and welfare. Failure to do so may result in respiratory problems and contact dermatitis in the birds.

2. Litter quality is partially related to the type of substrate, management of ventilation and water supply (prevention of spillage). The risk of contact dermatitis can be reduced by the choice and appropriate management of litter material and drinker systems.

3. Regular visual inspection of litter (e.g. during daily flock inspection) and avoidance of high moisture content and inspection of feet conditions from the first week of age onwards appears to be the key strategy to avoid foot pad dermatitis and other health problems.

4. The Welfare Quality® assessment protocol includes a system scoring litter quality in commercial flocks.

Temperature:

1. The risk of heat stress in broilers increases with age and with stocking density as heat production increases and as space between birds (and hence their ability to lose heat) decreases.

2. There are indications that fast and slow growing strains differ in the way they cope with warm environments.

3. The proportion of broilers showing panting or huddling behaviour can be used as indicator of thermal comfort of the birds.

Light:

1. Lighting programmes that provide shorter photoperiods during the first week of age would appear to confer benefits for broiler welfare without necessarily compromising performance.

2. Continuous or near-continuous lighting has negative effects on broiler behaviour and health as well as very short photoperiods; however, it is difficult to determine an optimal photoperiod or photoperiods for welfare because of the wide variety of photo schedules that have been studied. Several studies have shown that a continuous period of darkness of four hours as indicated in the EU Broiler directive should not negatively affect performance as compared to shorter continuous periods of darkness. However, intermittent lighting schedules that provide darkness in blocks of less than 4 continuous hours have also been shown to be beneficial in reducing metabolic and skeletal disorders. The age-dependent responses for feed intake and body weight gain mean that one photoperiod may not be appropriate for all slaughter ages.

3. Dim illumination (less than 10 lux) during the lights-on period also has negative effects on

broiler behaviour and leg and eye health. However, recent studies suggest that an illumination level of 10 lux is sufficient to promote normal behavioural rhythms and good skeletal and eye health. Levels above 10 lux may be associated with some decreases in yield.

4. Behaviour patterns of broilers are influenced by the contrast in intensity between the light and dark period, as well as by the absolute intensity level in the dark period. The effect of contrast in intensity on broiler welfare needs further research.

5. Since the four aspects of light interact with one another they cannot be considered independently. Thus, regulations or codes designed to standardise light levels need to take account of the fact that broilers may perceive the luminance from different light sources differently. In addition, it is important to consider not only daytime illumination levels, but night time illumination levels and the intensity contrast between the two.

Stocking density:

1. Although high stocking density has a negative influence on many aspects of broiler welfare, it is unclear to what extent these are in fact attributable to environmental factors that deteriorate with increased density (temperature, humidity, litter moisture). Also, it is unclear to what extent it is possible to prevent such a deterioration using improved climatic control, since air may be trapped between birds when they are stocked densely.

2. Large variation in environmental factors may obscure density effects studied in the field. However, even studies on commercial farms showed a decrease in growth rate and walking ability as stocking density increased, and increased disturbance of rest, as well as an increase in skin scratches, hock burn and foot pad dermatitis as stocking density increased which are all indicative of decreased welfare.

3. Studies on bird distribution, avoidance and motivation for birds to achieve lower stocking densities indicate that broilers prefer stocking densities that are lower than the maximum stocking density as indicated in the EU Broiler Directive.

Stockmanship:

1. The role and impact of the stockperson on animal welfare and productivity is paramount – also in broiler production.

2. There are indications that regular stockperson visual contact reduces fear and stress in broilers.

Environmental enrichment:

1. Enrichments are additions to the birds' environment that improve the welfare of the birds, e.g., by providing birds with cover, or by encouraging activity and desirable behaviours like perching. Perches should be considered as potential enrichment, although their use depend on factors like breed or especially perch design. Low horizontal barriers show particular promise in encouraging perching behaviour in fast growing strains.

2. Although enrichment is a promising area for research to improve broiler welfare, benefits should not be generalized, as results of the intervention may depend on multiple factors. Further research is needed to refine enrichment design in such a way that materials used are long lasting, easy to disinfect among successive flocks and are easy to apply.

3. Pilot studies under commercial conditions are required before their use can be recommended on a large scale.

Broiler catching:

1. Several studies compared manual catching with mechanical catching. If carried out properly, both methods may result in low levels of stress and injury. Some studies indicate that mechanical catching may lead to less injuries as compared to manual catching.

Nutrition

1. Mixing whole wheat into standard pelleted broiler feeds is common practice in several countries and may have positive effects such as better overall digestion and improving gut health.

2. It is apparent that even when growth rate and body size have been substantially altered by genetic selection, the underlying normal controls of feeding behaviour are conserved in broiler birds.

3. The energy, protein and amino acid contents of the diet are major factors determining the growth, feed efficiency and body composition of broilers.

4. Calcium and phosphorus are both essential for good bone formation and bone quality is more sensitive than growth rate as a criterion of the requirements for these nutrients.

5. Deficiencies of minerals and vitamins generally result in impaired performance and specific lesions that can be considered to be detrimental to the welfare of the bird.

6. Diets are supplemented with a number of additives aimed at improving performance or health of birds or the nutritive value of the diet (e.g. anticoccidial drugs, NSP enzymes, phytase).

7. Good nutrition is important for rearing healthy broilers. Overt nutrient deficiency is rare but more information on optimal dietary specifications for birds under stressful conditions might improve bird health and welfare.

8. Nutritional management can have an impact on metabolic disorders.

9. Nutrition influences litter quality in different ways, i.e. by the energy/protein ration, amino acid balance, dietary electrolyte balance, crude fat content and type of fat, and thus has an effect on the risk to develop contact dermatitis.

Water

1. Broiler chickens prefer drinkers to be at a lower rather than higher position to drink, corresponding to the natural 'scoop' action of drinking.

2. Water spillage should be prevented as it causes wet litter and increases the risk for contact dermatitis. Water spillage can be prevented by drip cups underneath the nipples. Lowering the water pressure, or reducing water intake by adding acids to the drinking water seem to have negative effects on broiler welfare and are not preferred by broilers.

3. A severe gait impairment imposes a risk for dehydration in broilers.

4. Due to practical limitations there are as yet no suitable animal-based measures for thirst in broilers. Thus far, the number of birds per drinker as used in Welfare Quality® seems the most useful indicator of absence of thirst in practice, provided the drinkers are accessible to all birds.

PROPOSED POSSIBLE AMENDMENTS TO CONCLUSIONS TO THE PREVIOUS EFSA REPORT (2010)
(Scientific opinion on the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers)

Musculoskeletal disorders:

1. There are some indications that incubation conditions may affect leg health, but further research is necessary.

2. Gait score is widely used to assess broiler leg health in commercial flocks. However, gait score cannot discriminate between underlying pathology or poor gait due to conformation.

Contact dermatitis:

1. Because of the relationship with management factors, flock health and the fact that foot and hock lesions are likely to be painful, FPD and hock burns are useful welfare indicators in broilers.

2. Hock and foot lesions likely have a partially different aetiology, where hock lesions are not only related to wet litter and ammonia concentrations in the litter (like FPD) but also to the weight of the birds.

Ascites and SDS:

1. Diet composition may affect the incidence of ascites.

2. The brooding process may affect the incidence of ascites post-hatching.

3. Low energy intake can decrease SDS and ascites because of a slower growth rate.

Thermal discomfort:

1. Brooding conditions may affect the ability of the animal to cope with heat stress later in life.

Digestive function

1. Suboptimal digestibility of feed may have a negative effect on litter quality and in this way affect cleanliness of the birds and the incidence of contact dermatitis.

PROPOSED POSSIBLE AMENDMENTS TO CONCLUSIONS TO THE PREVIOUS EFSA REPORT (2010)
(Scientific opinion on welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes)

Feed restriction:

1. The use of diets with a high proportion of insoluble fibre may alleviate sensation of hunger during rearing.

Aggression:

1. Improved management protocols (such as reducing stocking density or use of environmental enrichment) can be used to improve mating behaviour, reducing the frequency of force matings.

Mutilations:

1. Infrared trimming likely offers welfare and performance advantages over hot-blade trimming (according to studies in laying-strains).

Stocking density:

1. Reduction of stocking density may reduce feather damage and have positive effects on behaviour and hen performance.

RECOMMENDATIONS

RECOMMENDATIONS AND ASSOCIATED HAZARDS - CHAPTER 1

The original report (SCAHAW, 2000) did not include a list of hazards. Hazards were identified based on the information in the current sub-report and the hazard lists in sub-reports B and C.

	Recommendation in previous SCAHAW report (SCAHAW, 2000)	Suggested recommendation following the present evaluation	Hazard involved	Relevant paragraph
1	Welfare in broilers is to a large extent influenced by the quality of the stockmanship. Therefore, stockmen should be well trained for their tasks. The training should comprise biology of broilers as well as technical knowledge of the equipment and how to achieve optimal function of a system.	Further supported by new information.	Lack of appropriate training for stockpersons and animal handlers	1.5.6.
2	Broilers should be inspected every day. Animals with signs of poor health who are likely to suffer should be culled immediately and in a humane manner. Particular attention should be given to signs of poor leg condition, and animals with considerable difficulties in	See sub-report B for updated recommendations on mortality. Additional recommendation: Stockpersons should be trained for humane euthanasia protocols.	Lack of appropriate training for stockpersons and animal handlers Use of inappropriate culling methods	Culling methods will be covered by Regulation 1099/2009 from 2013.

	walking should be culled. Other signs that birds require immediate culling are severe ascites, malformations, severe wounds and seizures.			
3	It is essential that adequate monitoring schemes are set up and made publicly available. Monitoring schemes should be set up for continuous evaluation of leg health across broiler stocks, using the best available methods for objective assessment. Every building should have monitoring of ventilation functionality, air- and litter quality, and of animal health and mortality. Culling rates should always be included in any monitoring of mortality levels.	Delete; overlap with recommendations in chapter 2 (sub-report B).		NA[3]
4	Bone characteristics of broiler lines should be assessed to ensure that current selection procedures decrease the incidence of bone abnormalities. In addition, improving selection to minimise leg and muscular problems of broilers by genetic means, increased efforts should be made to address this problem by improving the nutritional and management methods.	See chapter 2 (sub-report B) for updated recommendations on musculoskeletal disorders		NA
5	The litter surface should be kept dry. A good litter quality also reduces the risk of contact dermatitis and problems with gas contaminants and can be achieved by using a litter material with high water-holding capacity. A water system which minimises water spillage should be used, such as water nipples with drip cups positioned at an appropriate height for all birds. Nipple drinkers alone should not be used. The ventilation capacity should be sufficient to avoid overheating and to remove excess moisture. The feed composition should be well balanced to avoid problems with wet or sticky droppings.	Litter should be of good quality, i.e. dry and friable, to prevent contact dermatitis and respiratory problems. An appropriate litter type/particle size and amount should be chosen that minimises the risk of high moisture levels. A water system that minimises spilling should be used, such as drip cups underneath the nipples, to prevent wet litter and to reduce the risk for contact dermatitis. Litter quality should be assessed on a regular basis (e.g. daily during flock inspection) and used as guideline for management (e.g., ventilation, temperature) to assure good litter quality	Lack of appropriate training for stockpersons and animal handlers Wet litter Crusted litter Inappropriate type and quality of water equipment Poor ventilation Inadequate ventilation capacity High humidity Low temperature Diet composition	1.5.2. 1.5.3. 1.6.2. 1.6.3.

[3] NA Not applicable

		and to prevent contact dermatitis.		
		The ventilation capacity should be sufficient and should be used to remove excess moisture.		
		The feed should be formulated, and the diet composition should be well balanced, to avoid problems with wet or sticky droppings and to reduce the risk for contact dermatitis.		
6	Every effort should be made to keep the "apparent equivalent temperature" (AET, a measure which combines temperature and humidity; see chapter 6.8) under 40ºC with five- to six-week old birds (younger birds will tolerate higher AET), by prevention of overstocking and moist litter, appropriate environmental monitoring and adjustment of ventilation rate. When birds show obvious panting ventilation levels and distribution should be adjusted and, if necessary, destocking should be carried out.	The ventilation capacity should be sufficient and used to avoid overheating of the birds. It should be monitored if birds show signs of overheating (panting behaviour) or being too cold (huddling) and ventilation capacity and environmental temperature should be adapted accordingly. Season should be taken into account for the choice of the initial stocking density. Less preferred is lowering stocking density by thinning, as it is a potential stressor and may introduce pathogens. An appropriate genetic strain should be selected according to the regional climatic conditions.	Lack of appropriate training for stockpersons and animal handlers Poor ventilation Inadequate ventilation capacity High temperature Low temperature High humidity Inappropriate breed Too high stocking density High growth rate High body mass	1.5.3.
7	Air quality, which is a complex of many aspects of air content, such as dust level and concentrations of CO_2, CO, and NH_3, should be controlled and kept within limits where the welfare of the broilers is not negatively affected. In particular, the concentration of NH3 should not exceed 20 ppm.	Air quality should be maintained at optimal levels. For CO_2, NH_3 and humidity upper limits are defined in the EU Broiler Directive. Dust levels should be kept to a minimum to prevent respiratory diseases and infections.	Inadequate ventilation capacity High humidity Bad air quality High temperature Low temperature Overly dry litter Diet composition Inappropriate type and quality of water equipment High stocking density Inappropriate type and quality of heating system	1.5.4.

8	Growing broilers should always receive at least 2 hours of darkness per 24 hours. Recommended average minimum light intensities (measured in three planes at right angles to each other) with incandescent lighting should be 100 lux for the first week and 20 lux thereafter. If fluorescent lighting is used, the light intensity can be 25% lower.	Continuous or near-continuous light as well as very short photoperiods should be avoided as these have negative effects on broilers' health and welfare. Lighting is regulated in the EU Broiler Directive.	Excessively long photoperiod Excessively short photoperiod Low light intensity Light spectrum	1.5.4.
		A light intensity of less than 10 lux should be avoided during the lights-on period as it has negative effects on behaviour and eye development. Lighting is regulated in the EU Broiler Directive.		
9	In order to keep the levels of stress and injury as low as possible during the catching process, staff carrying out the catching, regardless of whether it is done manually or mechanically, should be properly trained for the task. Sick or injured birds should be identified and removed or culled before the catching of the rest of the flock is commenced. All birds should be handled carefully. The equipment used, whether for manual or mechanical catching, should be designed and maintained in a way that reduces the risk of stress or injury to the birds.	Further supported by new information	Lack of appropriate training for catching crews Use of inappropriate culling methods	1.5.8. Culling methods will be covered by Regulation 1099/2009 from 2013
10	The welfare of breeding birds must be improved. The severe feed restriction needed to optimise productivity results in unacceptable welfare problems. However, industry is faced with a dilemma because allowing birds to reach a high body weight through free access to feed results in other serious welfare problems. New approaches are required to the breeding and management of broiler parent stock so that both the period and severity of feed restriction can be reduced considerably without adverse welfare consequences. Animals should be kept in such a manner that mutilations are not necessary.	See chapter 3 (sub-report C) for updated recommendations regarding broiler breeders		NA

11	Efforts should be made to develop a better fundamental understanding of the causes of skeletal and developmental leg abnormalities, with a view to establishing markers for more effective genetic selection against these disorders.	See chapter 2 (sub-report B) for updated recommendations regarding musculoskeletal disorders		NA
12	Research should be continued to identify optimum nutritional and environmental conditions for minimising leg problems.	See chapter 2 (sub-report B) for updated recommendations regarding musculoskeletal disorders		NA
13	An objective system should be developed for the assessment of leg quality and walking ability in commercial flocks.	See chapter 2 (sub-report B) for updated recommendations regarding musculoskeletal disorders		NA
14	Myopathies and biochemical indices of muscle damage have been identified in modern broilers. A better understanding is needed of whether or how changes in muscle physiology resulting from modern breeding practices have an impact on broiler welfare.	See chapter 2 (sub-report B) for updated recommendations regarding muscle disorders		NA
15	More information is needed on nutritional means of alleviating the various effects of stress.	Further supported by new information	Feed management Inappropriate diet	1.6.2.
16	Research is needed to identify genetic and management strategies for minimising the need of breeding birds for feed restriction.	See chapter 3 (sub-report C) for updated recommendations regarding broiler breeders		NA
17	More information is needed about efficient methods for the humane culling of broiler, both at individual and at flock level, in case of injury or disease.	See chapter 2 (sub-report B) for updated recommendations regarding mortality/culling		Culling methods will be covered by Regulation 1099/2009 from 2013
18	Commercial scale trials should be carried out in order to better estimate the economic effects of various measures designed to improve animal welfare. Even though it has been possible to evaluate the direct costs of various animal welfare regimes, the indirect effects, especially economic benefits, (reduction of certain aspects of the cost of production or improvements in the quality of the product) which could result from the improvements in welfare for the chicken remain to be quantified.	Economic consequences were not covered in this update.		NA

19	Research should be carried out on the relationship between light intensities and broiler welfare.	See #N7.	Excessively long photoperiod Excessively short photoperiod Low light intensity Unpredictable light schedule Light spectrum	1.5.4.2.
N1	Birds should be selected for motivation for activity to increase mobility (recommendation originating from chapter 2 - sub-report B)	Further supported by new information. Communication among geneticists and experts in broiler welfare should be stimulated.	Improper weighting of traits[4] Fast growth rate High body weight	1.4.9.
N2	Management systems that encourage bird mobility should be developed (recommendation originating from chapter 2 - sub-report B)	Addition: This can be done by environmental enrichment that stimulates locomotion and reduces litter contact.	Barren environment Inappropriate enrichment Inappropriate breed Improper weighting of traits Fast growth rate High body weight	1.4.9. 1.5.7.
N3		Environmental enrichment, such as perches or cover panels, should be provided as it stimulates locomotion and decreases disturbance of rest.	Barren environment Inappropriate enrichment Inappropriate breed High body weight	1.4.9. 1.5.7.
N4		Broilers should be fed well-balanced diets to prevent health problems	Inappropriate diet	1.6.1. 1.6.2.
N5		Nutritional management (diet composition as well as feeding management) should be used to decrease the risk for metabolic disorders and contact dermatitis. Communication among nutritionists and experts in broiler welfare should be stimulated.	Inappropriate diet Inappropriate feeding management	1.6.1. 1.6.2.
N6		Although studies have not indicated a clear critical stocking density yet, too high densities put welfare at risk by increased disturbance frequency and limited movement of the birds, but may also have an economic impact. Physical monitoring indicates insufficient space above 40 kg/m^2, suggesting that this may be an upper limit, but this needs to be confirmed by additional research.	High stocking density	1.5.5.

[4] Improper weighting of traits: selection pressure is more on other traits than on welfare aspects such as gait or susceptibility for contact dermatitis

		The recommendations below refer specifically to future research:		
20	Research should be continued to identify nutritional methods for controlling pathogens and optimising immunological competence and health in broilers in the absence of growth promoting antibacterials.	Research should continue to identify nutritional methods for controlling pathogens and optimising immunological competence and health in broilers	Inadequate feed management Inappropriate diet	1.6.2.
21	Research should be conducted to closer elucidate the behavioural needs of broilers. In particular, it is not known to what extent the reduced activity in broilers is caused by a simple physical incapacity to carry out physical activity, or to what extent it is caused by reduced motivation for active behaviour. The genetic correlations between growth and behavioural responses also needs closer study.	Despite several studies indicating that high body weight causes decreased activity, more research is needed to the behavioural need of broilers, motivation or physical ability. The genetic correlations between growth and behavioural responses also requires further study.	Fast growth rate High body weight Improper weighting of traits Inappropriate breed	1.4.9.
22	More research is needed on different methods of environmental enrichment for broilers, for example the use of perches, etc.	Further research is necessary to identify appropriate and effective enrichment designs, as well as to the application of environmental enrichment under commercial conditions. Commercial scale tests are needed to examine enrichment effects in industry settings.	Barren environment Inappropriate enrichment	1.5.7.
N7		The effects of the different aspects of light, i.e. light intensity, photoperiod, light source and wavelength, on broiler welfare and the interaction between these factors requires further research.	Excessively long photoperiod Excessively short photoperiod Low light intensity Light spectrum	1.5.4.
N8		The relation between the contrast in illumination level between the light and dark period as well as the absolute illumination level in the dark period and broiler welfare needs further research.	Low/very high light intensity Low light contrast between light and dark period	1.5.4.2
N9		Broilers prefer lower rather than higher drinkers as that promotes the natural drinking behaviour, however, it is unclear if drinker height may negatively affect broiler welfare which requires further research.	High position of drinkers	1.6.3.
N		It should be encouraged to	High stocking density	1.4.9.

10		further study optimal densities at commercial level that minimizes welfare hazards for each region and management system.		1.5.5.
N 11		Further research to a critical stocking density at which welfare is impaired is needed, not only for stocking densities near slaughter age but also for stocking densities at young ages.	High stocking density	1.5.5.
N 12		Studies to the effects of stocking density on broiler welfare at commercial scale should try to unravel the effects of decreased environmental conditions that often coincide with increased stocking density, and the stocking density in itself.	High stocking density High environmental temperature High humidity Wet litter Crusted litter Bad air quality	1.5.5.

RECOMMENDATIONS AND ASSOCIATED HAZARDS – CHAPTER 2

New recommendations as compared to the previous report (EFSA, 2010) are in italics.

	Recommendation in previous EFSA report (EFSA, 2010)	Suggested recommendation following the present evaluation	Hazard involved	Relevant paragraph
1	Surveillance systems to collect relevant data on broiler welfare, including health, in Europe should be put in place to monitor trends in the prevalence and magnitude of poor welfare (i.e. degree of suffering) of leg problems, footpad dermatitis, ascites and sudden death syndrome in commercial flocks. This would also help to identify emerging problems.	No change	See hazards below for the specific welfare issues	NA[5]
2	Data on welfare outcome indicators such as mortality, found dead and culling rates should be recorded. In addition, the reasons for mortality and culling, the numbers of birds found dead, gait scoring and ascites in commercial rearing conditions should be recorded and made publicly available by breeding companies for each genetic line of broilers. This information could be used by farmers when selecting lines to purchase and by competent authorities checking on welfare.	No change	Lack of appropriate training for stockpersons and animal handlers Use of inappropriate culling methods See hazards below for the specific welfare issues	NA
3	Decreasing the proportion of birds with gait score 4 and 5 should receive a high priority and should be addressed through increased selection pressure on all factors contributing to high gait scores as well as through improved management.	Further supported by new information	High stocking density Light schedule Low light intensity Inappropriate diet Barren environment Fast growth rate High body mass Unbalanced body conformation Reduced mobility Inappropriate incubation process and poor hatchery hygiene	2.1.2.
4	Gait scoring should be carried out in a standardised way on all broiler production and breeding farms. If a significant proportion of birds have scores of 3 and above then this should trigger a	Further supported by new information	High stocking density Light schedule Low light intensity Inappropriate diet Barren environment Fast growth rate	2.1.2.

[5] Not applicable

			High body mass Unbalanced body conformation Reduced mobility Inappropriate incubation process and poor hatchery hygiene	
	review of systems of genetic selection, management or housing to be changed to improve the birds welfare. Thresholds of concern should be established and depending on the threshold chosen, it is expected that the eradication of this welfare problem will take some years.			
5	Birds that move with difficulty, or not at all, (gait scores 4 and 5) should be culled.	No change	High stocking density Light schedule Low light intensity Inappropriate diet Barren environment Fast growth rate High body mass Unbalanced body conformation Reduced mobility Inappropriate incubation process and poor hatchery hygiene	NA
6	Breeding companies should be encouraged to identify traits suitable for selection that would improve gait scoring of birds in their commercial lines.	No change	Improper weighting of traits6	NA
7	Contact dermatitis has a moderate degree of heritability and should be included in selection programmes.	Further supported by new information	Improper weighting of traits	2.1.4.
8	A standard classification system for contact dermatitis should be developed in Europe.	No change	Wet litter Crusted litter Diet composition Reduced mobility High stocking density Low light intensity Light cycle (long photoperiod) High body weight Improper weighting of traits	NA
9	There should be an objective by the industry to decrease the proportion of birds with contact dermatitis over the next 10 years through management and genetic selection.	Further supported by new information	Wet litter Crusted litter Diet composition Reduced mobility High stocking density Low light intensity Light cycle (long photoperiod) High body weight Improper weighting of traits	2.1.4.
10	Selection against Ascites and SDS, particularly in fast growing lines, should continue and the prevalence needs to be monitored to ensure it remains at a low level.	Further supported by new information	Fast growth rate Low ambient temperature Unrestricted feeding Diet composition Light cycle (long photoperiod) Inappropriate incubation	2.1.5.

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[6] Improper weighting of traits: selection pressure is more on other traits than on welfare aspects such as gait or susceptibility for contact dermatitis

			process High light intensity Improper weighting of traits	
11	Birds should be selected for motivation for activity to increase mobility.	See recommendations in chapter 1-sub-report A.		
12	Management systems that encourage bird mobility should be developed.	See recommendations in chapter 1-sub-report A.		
13	Management techniques should be adapted to avoid heat stress in birds.	Further supported by new information	High temperatures and humidity Poor ventilation Fast growth rate Diet composition Inappropriate breed Inappropriate incubation process	2.1.7.
14	Ambient temperature in the environment and genetic strain should be compatible to reduce heat stress. This may also mean reducing the growth rate by management techniques.	Further supported by new information	High temperatures and humidity Poor ventilation Fast growth rate Diet composition Inappropriate breed Inappropriate incubation process	2.1.7.
15	A standardised system for recording respiratory and mucous membrane diseases at the slaughterhouse should be developed.	No change	High stocking density Wet litter Overly dry litter Poor ventilation	NA
16	Welfare traits that are found to be heritable should be included in breeding programmes and selection indices and should also be included in the genetic selection and interaction with the environment studies.	No change	Improper weighting of traits	NA
17	Genetic diversity should be maintained by breeding companies in order to meet future market demand and to develop lines that can withstand challenging environments.	No change	Improper weighting of traits	NA
18	Slower growing lines should be used and should be selected further for hot climates.	No change	Improper weighting of traits High temperature	NA
19	There should be standardised (objective) monitoring of welfare in commercial flocks in a system harmonised across different countries, to assess phenotypic trends of various traits as well as the impact of genetic selection on these traits.	No change	Improper weighting of traits See hazards for the specific welfare issues	NA
20	Breeding companies should test and follow-up more closely the	No change	Improper weighting of traits Inappropriate breed	NA

	ability of the birds to adapt to different kinds of environments from welfare as well as productivity and marketing perspectives, and not simply on a „no complaints basis". This will provide better information on genetic selection and interaction with the environment for future selection.			
21	Breeders and farmers should select birds able to adapt to the local environment, so that their welfare is good.	No change	Improper weighting of traits Inappropriate breed	NA
22	An independent monitoring system that provides information on welfare and production, should be provided to farmers for them to make a suitable choice of breed for their specific circumstances.	No change	Improper weighting of traits Inappropriate breed	NA
23	Genomic selection and other new technologies should be considered when selecting welfare related traits.	No change	Improper weighting of traits	NA
	The recommendations below refer specifically to future research:			
24.	Further research is needed on causes of reduced mobility and associated welfare implications e.g. pain, social interactions.	Further supported by new information	High stocking density Light schedule Low light intensity Inappropriate diet Barren environment Fast growth rate High body mass Unbalanced body conformation Reduced mobility Inappropriate incubation process	2.1.2.
25	Further research is needed on the interaction of environmental factors and genetics with regard to welfare.	No change	Improper weighting of traits Inappropriate breed See hazards for the specific welfare issues	NA
26	Studies are needed in order to develop practical methods for independent health and welfare surveillance and to objectively assess and record welfare indicators in broiler flocks.	No change	See hazards for the specific welfare issues	NA
N1		Further research to the relation between incubation conditions and welfare issues like gait	Inappropriate incubation process and poor hatchery hygiene	2.1.2. 2.1.5.

			abnormalit ies, thermal discomfort and ascites is needed.		

RECOMMENDATIONS AND ASSOCIATED HAZARDS – CHAPTER 3

Additional hazards to the previous report (EFSA, 2010) are in italics.

	Recommendation in previous EFSA report (EFSA, 2010)	Suggested recommendation following the present evaluation	Hazard involved	Relevant paragraph
1	Quantitative data should be collected on housing and management systems, in particular the allocation of perches and other environment enrichments.	No change	Barren environment High stocking density Inappropriate enrichment Poor housing design and allocation of resources High stocking density High/low light intensity Wet/overly dry litter	NA[7]
2	Sufficient perch or platform space should be provided during rearing so that birds learn to navigate in a three-dimensional space and later during the production to provide sufficient space for all those birds that use them.	No change	Barren environment	NA
3	Cages for breeding birds should meet the same legal requirements, for litter, nest box and perches, as for laying hens.	Cages for breeding birds should meet the same legal requirements, for litter, nest box and perches, as for laying hens. As broiler breeders should be able to perform mating behaviour, more space per bird might be necessary as compared to laying hens.	Conventional cages	3.2.2.
4	Birds that require less feed restriction should be selected as future breeders. This may involve reduced selection pressure on high growth rates.	Further supported by new information	Genetic selection for fast growth	3.2.1.
5	The trend in the degree of	No change	Feed restriction	NA

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[7] NA not applicable

	feed restriction required to maintain broiler breeder bodyweight targets should be monitored.			
6	A feather and injury scoring method should be developed to measure the level and extend of damage caused by aggressive behaviour.	A feather and injury scoring method should be developed to measure the level and extend of damage caused by aggressive interactions and forced matings.	*Feeding practices* Feed restriction Inappropriate diet Low light intensity High light intensity *Male-male competition for matings* Poor housing design and allocation of resources	3.2.2.
7	Management of the distribution of the feed should minimize competition between birds and reduce injuries.	No change	*Feeding practices* Feed restriction	NA
8	The possible impact on welfare of alternative feeding strategies should be evaluated.	Further supported by new information	Feed restriction Unrestricted feeding	3.2.1.
9	Males should not be introduced until the females are sexually mature.	Males should not be introduced until the females are sexually mature, or growth should be managed in such a way that one is sure that females mature before males.	*Male management* High stocking density Environmental enrichment	NA
10	Quantitative data on the prevalence and effectiveness of the different types of mutilations such as beak trimming, de-toeing and de-spurring and the methods used should be collected.	Further supported by new information	Beak trimming Despurring Detoeing Dubbing	3.2.3.
11	No mutilation with effect on welfare as severe as those resulting from cutting off toes or dubbing should be carried out unless justified by evidence for substantial and unavoidable level of poor welfare in other birds.	Further supported by new information	Beak trimming Despurring Detoeing Dubbing	3.2.3.
12	Mutilations should be carried out by trained personnel using the least painful methods.	Mutilations should be carried out at the right age by trained personnel using the least painful methods.	Lack of appropriate training for stockpersons and animal handlers	3.2.3.

13	Training for those who cull broiler breeders should be put in place.	No change	Lack of appropriate training for stockpersons and animal handlers	NA
14	Transport crates (size, and height) should be appropriate to the size of birds, and slaughterhouse facilities should have shackles and stunning procedures equipped for adult broiler breeder birds.	No change	Lack of appropriate training for stockpersons and animal handlers	NA
15	A standardised gait scoring system should be developed for broiler breeders so that it can be used to assess leg disorders and associated pain.	A specific standardised gait scoring system should be developed for broiler breeders so that it can be used to assess leg disorders and associated pain. If prevalence of leg disorders is high, then a monitoring system should be put in place with associated thresholds for action (e.g. culling).	Reduced mobility	NA
16	The results of monitoring infectious disease in broiler breeders should be recorded.	No change	Poor ventilation High stocking density Overly dry litter	NA
17	There is generally a lack of surveillance in broiler breeder disease and there is a need to have up-to-date information on the incidence and prevalence of contact dermatitis conditions, leg weakness as well as other diseases.	No change	Poor ventilation High stocking density Overly dry litter Wet litter Inappropriate diet	NA
N1		Training for catchers should be put in place.	*Lack of appropriate training for catching crews*	NA
	The recommendations below specifically relate to potential animal-based indicators as well as monitoring trends over time:			
18	The systematic recording of mortality and culling rates (and/or a new indicator combining these) as well as culling methods, should be instigated and evaluated as potentially useful indicators of welfare and to monitor trends. A welfare outcome indicator should then be developed that expresses culling and mortality as a proportion of all dead birds.	No change	Poor ventilation High stocking density Overly dry litter Wet litter Lack of appropriate training for stockpersons and	NA

			animal handlers *Poor biosecurity*	
19	The prevalence of footpad lesions and hock burns in broiler breeders should be determined based upon the methods established for broilers. If the prevalence is high, then systematic recording should be instigated to monitor trends.	No change	Wet litter *Diet composition*	NA
20	To modify a standardised gait scoring system developed for broilers so that it can be used to determine the prevalence of leg weakness in breeding birds. If the prevalence of the worst gait scores is high, then systematic recording should be instigated to monitor trends.	Overlap with #16		
21	The prevalence of feather damage, skin damage and other injuries (including pecking damage to the comb) should be determined using the methods established for broilers and laying hens. If the prevalence is high, then systematic recording should be instigated to monitor trends in the levels of aggression and abnormal behaviour.	The prevalence of feather damage, skin damage and other injuries (including pecking damage to the comb) should be determined using the methods established for broilers and laying hens. If the prevalence is high, then systematic recording should be instigated to monitor trends in the levels of aggression and abnormal behaviour with associated thresholds for action.	High stocking density Feed restriction	3.2.7.
22	Data on welfare measures, such as „dead on arrival" should be collected at the slaughterhouse.	No change	Lack of appropriate training for stockpersons and animal handlers	NA
23	The potential of using the incidence of spot pecking and over drinking as welfare outcome indicators related to hunger should be evaluated.	No change	Feed restriction	NA
24	The potential of using the proportion of birds perching at night time as a welfare outcome indicator of appropriate provision of perches	No change	Barren environment	NA

	should be evaluated.			
	The following recommendations relate specifically to future research:			
25	Research to evaluate the potential acute and chronic pain associated with de-toeing and de-spurring as well as the consequence for the welfare of other birds of not performing these mutilations should be obtained.	No change	Detoeing Despurring Beak trimming Comb dubbing	NA
26	Further research on the relationship between hunger and feed restriction is needed, to limit the negative welfare effects, particularly in broiler breeder males.	Further research on the relationship between hunger and feed restriction, as well as on better feeding strategies to better balance hunger and health problems and to reduce feed restriction is needed, to limit the negative welfare effects. This is particularly important in broiler breeder males.	Feed restriction	3.2.1.
27	Future studies should focus on the behaviour of restricted fed birds in commercial flocks.	No change	Feed restriction	NA
28	Future research should focus on management strategies to alleviate the hunger associated with feed restriction during rearing, e.g. to determine an appropriate level of restriction to the point where birds are not hungry but do not suffer from health problems linked with unrestricted feeding	Overlap with #26		
29	Future research should focus on reducing injuries to females during mating and on the genetic components that could be used to reduce aggression during mating.	Future research should focus on reducing injuries to females during mating and on the management and genetic selection strategies that could be used to reduce	High stocking density Barren environment	3.2.2.

			injuries to females during mating and to improve reproductive efficiency.		
30	As cover panels seem to prevent excessive mating in broiler breeders they should be tested at European production farms.	No change		Barren environment *Male-male competition for matings Female stress*	NA
31	There is a need for more research specifically on broiler breeders and the practical application of environment enrichment in particular comfortable and secure resting facilities.	There is a need for more research specifically on broiler breeders and the practical application of management practices and environment enrichment.		Barren environment Poor housing design and allocation of resources Inappropriate enrichment	NA
32	Welfare outcome indicators should be developed for assessing welfare at the abattoir such as: temperature of birds, feather cover and skin injuries, dead on arrival.	Welfare outcome indicators should be developed for assessing welfare at the abattoir such as: temperature of birds, feather cover and skin injuries, footpad dermatitis, dead on arrival and body weight variation.		High stocking density Feed restriction Lack of appropriate training for stockpersons and animal handlers Wet litter	NA
33	Future research should focus on the impact of spiking on animal welfare.	Future research should focus on the impact of spiking on fertility and animal welfare.		*Introduction of males*	3.2.2.
34	The impact of the reduction of growth rate on welfare, health (and performances) of breeders (hunger, frustration, metabolic disorders…) should be investigated.	No change		Genetic selection for fast growth	NA

N1		The impact of management on forced mating behaviour should be further evaluated	High stocking density *Male management Male-male competition for matings Introduction of males*	3.2.2.

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