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Brief of Requirements of the Broiler

Broilers with taste/ Pluimvee met smaak

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Abstract
This report lists the brief of requirements of the broiler, based on her needs (also listed). The BoR indicates the actor's needs with regards to the animal husbandry system. BoR of the main actors are incorporated in the redesign of a broiler husbandry system in the project Tasteful Broilers.

Keywords
Animal welfare, broiler, brief of requirements, needs, design

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Programma van Eisen van het Vleeskuiken

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Preface

Animal welfare is a key issue in societal debates on the future of animal production in Western countries like the Netherlands. Yet, improving the living conditions of animals has to be paired with a range of other sustainability (i.e. economic or ecological) requirements. More often than not, these requirements seem to contradict each other if we try to improve current systems by adaptation. In a series of projects (see www.duurzameveehouderij.wur.nl), Wageningen Livestock Research has shown that this seeming tension can be solved if we allow ourselves to redesign husbandry systems from scratch. By focusing on the needs of the prospective actors, including the animal, and translating these needs into requirements, a structured design process is possible that opens up new ways to solve the wicked problems that prevent the current systems from becoming substantially more sustainable. Explicating the needs and requirements of the animal is especially important, since the animal cannot speak for itself, and its needs are easily compromised to fulfil economical or ecological requirements.

In this report, this explication is done for the broiler. A large part of the available scientific literature on the environmental requirements relevant for animal welfare of broilers is translated into a concise list of design requirements for husbandry systems for broilers that do not compromise their needs. Anyone interested in the design of such new systems can benefit from this work, since it does not assume specific solutions beforehand: requirements are formulated in such a way that a range of possible solutions can be envisioned to fulfil them.

In the Brief of Requirements the ideal level for the broiler has consistently been chosen for each requirement. This means that any design based on meeting these requirements will have a very good chance of realizing a high level of animal welfare for broilers, based on the current body of knowledge. Of course there are several limitations to this since important empirical research is still lacking on certain needs, and too little is known of the differences between broilers with different growth rates. The report thus can also be read as an agenda for further empirical studies to fill in these gaps.

The redesign project ‘Tasteful Broilers’ (‘Pluimvee met Smaak’ in Dutch) has already made good use of this report in its second and final design stage. More information on the design outcomes are available on the website: www.pluimveemetsmaak.wur.nl. We thank the Dutch Ministry of Economics, Agriculture and Innovation for the financial support of this study within the projects Pluimvee met Smaak (BO-12.02-001-050.02) and Verankering Ontwerpen (BO-12.02-001-051).

Bram Bos

Samenvatting

Dit rapport is onderdeel van het project “Pluimvee met Smaak” dat is uitgevoerd door een projectgroep van Wageningen UR Livestock Research, in opdracht van het Nederlandse Ministerie van Economische Zaken, Landbouw en Innovatie. Het uiteindelijke doel van dit project is om nieuwe, integraal duurzame houderijsystemen te ontwerpen voor vleeskuikenproductie. Hierbij ligt de focus op de behoeften van de verschillende partijen betrokken bij de productie van pluimveevlees. In dit rapport zijn de behoeften en de bijbehorende eisen van één partij, de vleeskuikens, in kaart gebracht. Deze eisen, welke aan de omgeving gesteld worden om in de behoefte te kunnen voorzien, zijn gekwantificeerd in het begeleidende Programma van Eisen. Voor dit project worden drie verschillende types vleeskuikens onderscheiden, welke gedefinieerd kunnen worden als snel groeiende, middel snel groeiende en langzaam groeiende vleeskuikens. Het voornaamste verschil tussen deze drie types vleeskuikens is de groeisnelheid. Snel groeiende vleeskuikens bereiken hun slachtgewicht van twee kilo op een leeftijd van 42 dagen, terwijl middel snel groeiende vleeskuikens dit gewicht bereiken op een leeftijd van 56 dagen en langzaam groeiende vleeskuikens hier 84 dagen voor nodig hebben. Om de behoeften en eisen van deze vleeskuikens te identificeren is een diepgaand literatuuronderzoek verricht, waarbij voornamelijk studies gepubliceerd in erkende wetenschappelijke tijdschriften gebruikt zijn. Waar nodig is dit aangevuld met extra informatie uit grijze literatuur, expert opinie en de praktijk.

De behoeften, welke hier zijn geïdentificeerd voor vleeskuikens, zijn onderverdeeld in drie categorieën, namelijk de behoeften gerelateerd aan gedrag, de behoeften gerelateerd aan gezondheid en de behoeften gerelateerd aan voeding. De gedragsbehoeften bestaan uit behoefte aan foerageren en exploreren, rusten/slapen, zonnebaden, poetsen, stofbaden, vleugel/poot strekken, sociale interacties/spelen, en beweging. De behoeften gerelateerd aan gezondheid bestaan uit eisen gesteld aan de aanwezige lucht, temperatuur, micro-organismen en inrichting. Met betrekking tot de voeding zijn behoeften gespecificeerd voor de kwaliteit van voer en drinkwater. Voor al deze categorieën zijn de behoeften en eisen tot in detail verklaard in dit rapport, teneinde theoretische ondersteuning en uitleg te bieden voor het Programma van Eisen.

Ondanks dat een groot aantal wetenschappelijke studies en diverse andere informatiebronnen gebruikt zijn, was het niet mogelijk om elke behoefte en eis compleet te onderbouwen met wetenschappelijke data. Voor enkele behoeften, bijvoorbeeld de behoefte voor cognitieve stimulering door de omgeving, werd desondanks intuïtief aangevoeld dat een dergelijke behoefte van belang is voor vleeskuikens. In deze gevallen is dan ook besloten om deze behoeften toch op te nemen in het Programma van Eisen, ook al is niet bewezen in hoeverre deze behoeften belangrijk zijn voor vleeskuikens. Verder geeft het Programma van Eisen ook aan waar momenteel kennis ontbreekt met betrekking tot het welzijn van vleeskuikens, bijvoorbeeld over de mogelijk negatieve effecten van het ontbreken van een broedse hen tijdens de vroege ontwikkeling. Op deze punten identificeert dit project aanknopingspunten voor toekomstig onderzoek naar het welzijn van vleeskuikens.

De behoeften en eisen zoals besproken in dit rapport en het Programma van Eisen zijn niet gerangschikt op mate van impact op het welzijn van vleeskuikens, aangezien de formatie van een dergelijke rangorde geen onderdeel was van het project. Dit project laat echter wel duidelijk zien dat een vleeskuiken minimaal voorzien moet worden van voldoende ruimte om in zijn gedragsbehoeften te voorzien, voldoende en kwalitatief goed water en voer moet krijgen om zijn voedingsbehoeften te bevredigen, en in een schone omgeving gehouden dient te worden om gezond te blijven.

Summary

This report is part of the project “Tasteful Broilers”, which was commissioned by the Dutch Ministry of Economics, Agriculture and Innovation to be carried out by Wageningen UR Livestock Research. The ultimate goal of this project is to design a new sustainable form of broiler production, based on the needs of the different groups of actors involved in broiler production. In this report the needs of one such actor, namely the broiler, are identified and the requirements associated with these needs are reviewed. Quantifications of the requirements are given in the accompanying Brief of Requirements. Three types of broilers are distinguished here, defined as fast, medium and slow growing broilers. The main difference between these different strains of broilers is their growth rate, with fast growing broilers reaching their slaughter weight of two kg at 42 days of age and medium growing broilers at 56 days of age, while slow growing broilers grow for 84 days before reaching a similar body weight. A vast body of scientific literature was used to formulate the needs and requirements of these broilers, supplemented with grey literature, expert opinions and practical knowledge.

The needs identified for broilers are divided in three categories, namely behavioural needs, health related needs and nutritional needs. The behavioural needs contain the need for foraging and exploration, resting/sleeping, sun bathing, preening, dust bathing, wing/leg stretching, social interaction/play, and locomotion. The health related needs include the requirements for aerial, thermal, microbial and spatial environment. The nutritional needs are divided in needs and requirements for food and drinking water. For each category the needs and requirements are explained in further detail in this report, to provide theoretical support and explanations for the quantifications in the Brief of Requirements.

Even though a large number of peer-reviewed studies and other information sources were consulted, not all needs and requirements could be scientifically underpinned. For some needs, such as a need for cognitive stimulation by the environment, it could however be argued intuitively that such a need would exist in broilers. It is thus decided to include such needs in the Brief of Requirements even though their relative importance is not (yet) scientifically determined. The Brief of Requirements furthermore indicates the presence of some knowledge gaps where the welfare of broilers is concerned, for instance on the possible detrimental effects of the absence of a broody hen during early development. As such, this project can be used as reference point for further research on the welfare of broilers.

The needs and requirements discussed here are not ranked according to their relative importance for the welfare status of a broiler, as such a ranking was beyond the scope of this project. However it can be stated that a broiler should minimally be provided with sufficient space to fulfil its behavioural needs, with high quality food and drinking water to fulfil its nutritional needs, and be kept in a clean environment to meet its health related needs.

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1 Introduction

This report is part of the project “Tasteful Broilers” (in Dutch: “Pluimvee met Smaak”) which is carried out by Wageningen UR Livestock Research and is commissioned by the Dutch government. The aim of this project is to enhance the welfare of chickens kept for meat production, also called broilers, in the commercial broiler industry without compromising other aspects of chicken meat production, such as product quality, costs, environmental sustainability or working conditions. In line with the approach of Bracke and colleagues (1999ab), Bos and Groot Koerkamp (2009) and earlier projects similar in design such as “Keeping and Loving Hens” (in Dutch: ”Houden van Hennen” [Projectgroep Houden van Hennen, 2004]) and “Cow Power” (in Dutch: “Kracht van Koeien” [Cornelissen et al., 2009]), the needs and requirements of fast, medium and slow growing broilers are formulated and laid down in this Brief of Requirements (BoR).

In this report, first the conceptual foundation of the BoR is explained and commonly encountered problems in broiler production systems are shortly discussed in relation to the needs and requirements of broilers. The needs and requirements of broilers as identified in the course of this project are then reviewed. Some additional information is given to provide more insight in the relevance of these needs and requirements. Finally the findings of this project are discussed and some focus points for future research are indicated. In Appendix I a glossary is presented with definitions for the terminology used in this report and the BoR.

2 Design of the Brief of Requirements for Broilers

Several definitions of animal welfare have been proposed in scientific literature, either objectively or subjectively stated (e.g. Broom, 1986; Dawkins, 1988; Bracke et al., 1999a). The formulation of the following BoR was based on the definition of welfare as stated by Bracke et al. (1999a): "the animal's quality of life as it is experienced and valued by the animal itself" (Bracke et al., 1999a p.282). The state of welfare of an animal can be related to homeostatic control mechanisms that have developed in the course of evolution to promote survival and reproduction in a variable environment. A number of these mechanisms are based on motivational systems, in which 'needs', i.e. signals that induce a particular physiological and/or behavioural response, play a central role (Bracke et al., 1999b). To fulfil its needs the animal requires specific components in its environment. The components food and water for example are necessary to fulfil nutritional needs. It is assumed that the welfare of an animal is uncompromised when all its needs are fulfilled (Bos and Groot Koerkamp, 2009). Prolonged failure to fulfil a need leads to stress, which may result in e.g. abnormal behaviour (Duncan, 1998). A scientific approach towards welfare assessment has been proposed which is based on the state of an animal's needs, i.e. the extent to which its needs are satisfied or remain unfulfilled (Bracke et al., 1999ab). Following the ideas of Bracke and colleagues (1999ab) and the approach proposed by Bos and Groot Koerkamp (2009), this BoR was based on the needs and requirements that were identified for broilers kept in the modern meat industry.

2.1 Current Problems in Broiler Husbandry

The growth rate of broilers, i.e. chickens kept for meat production, has increased drastically over the past decades due to genetic selection for high growth rate and low feed conversion ratio (Bessei, 2006). Nowadays, fast growing broilers kept in conventional, commercial broiler production systems are able to reach their slaughter weight of 2100 grams in less than 40 days (Bokkers and de Boer, 2009). In comparison, a strain with a growth rate representative for broilers in 1957 required more than 84 days to reach a similar weight (Havenstein et al., 2003). Such high growth rates however can have detrimental effects on broiler health, by for instance increasing incidence of metabolic disorders, leg weakness and contact dermatitis (e.g. Ekstrand et al., 1997; Bizeray et al., 2000; Anonymous, 2001; Bradshaw et al., 2002; Jones et al., 2005b; Pagazaurtundua and Warriss, 2006).

Furthermore, selection for growth rate lead to differences in activity levels and physiology of the chickens. Overall activity levels of fast growing broilers are decreased (e.g. Bizeray et al., 2000; Bokkers and Koene, 2003a; Branciari et al., 2009), although the range of behaviours does not seem to be affected, i.e. the same active behaviours are performed but to a lesser extent (Bokkers and Koene, 2003a). Reduced activity levels can in turn lead to increased leg weakness and other health problems (Bradshaw et al., 2002). With regard to physiology, the hunger and satiety mechanisms of fast growing broilers are altered when compared to those of slower growing chickens (Bokkers and Koene, 2003b; Nielsen, 2004). Eating behaviour of broilers seems to be regulated only by satiety mechanisms in contrast to hunger mechanisms, i.e. broilers continuously eat to their maximal physical capacity (Bokkers and Koene, 2003b).

Additionally, management factors such as stocking densities, i.e. number of animals kept per m^2, litter quality, lighting regime and air quality can influence the severity of existing health problems (Bessei, 2006; Shepherd and Fairchild, 2010). Another problem often encountered in conventional production systems is that broilers are not able to fulfil their behavioural needs due to environmental restrictions (Anonymous, 2001; Simsek et al., 2009) even though they are motivated to do so (Bokkers and Koene 2004; Bokkers et al., 2004, 2007). When broilers cannot carry out their behavioural needs they become frustrated, which leads to stress and possibly physiological and/or behavioural problems (Duncan, 1998).

2.2 Formulating the Brief of Requirements

An important step towards increasing the welfare of broilers involves adjusting their environment to meet the chickens' needs. However, in order to do so, the needs of broilers should first be clearly identified. The aim of this BoR was to give an exhaustive and quantitative overview of the needs and requirements of broilers. This overview is based on an extensive body of literature reporting empirical research with broilers on the relation between animal welfare, animal behaviour and their environmental circumstances. In total more than 400 articles were read, of which 158 articles were found to contain relevant data for this BoR and report. These 158 articles contained 146 peer-reviewed articles, 8 articles from grey literature and 4 extension advice articles from broiler breeding companies. The procedure to interpret and translate these studies into the format of a BoR was adopted from Bos and Groot Koerkamp (2009).

The overall aim of the project "Tasteful Broilers" is to create designs for sustainable broiler production systems that are able to fulfil one need without compromising another. Thus the broiler requirements were formulated in a solution-free manner, i.e. without implicitly or explicitly including a specific solution for fulfilment of the needs. As such the number of possible solutions to integrate animal welfare with other issues of sustainability in broiler production systems was maximized, instead of trading these issues off against each other (Bos and Groot Koerkamp, 2009).

Note that the quantification of requirements as given in the BoR do not indicate the bare minimum to which a broiler can adapt in order to survive, but instead indicate the preferred value, i.e. the value that does not compromise its need. In some cases it was found that different studies that were consulted had (slightly) different values for the same requirement. In such instances, quantification of the requirement in this BoR was based on one value at the end of a spectrum by following the 'precautionary principle', i.e. choosing the value which would have the lowest probability of compromising the need, or causing harm, even if no conclusive scientific evidence was available to indicate that harm would indeed occur at the other end of the spectrum, and how severe the impact of such harm on broiler welfare would be. For example, for quantification of spatial requirements, i.e. the amount of space one broiler needs to perform a certain behaviour, the highest value within the range found was chosen. Similarly, for quantification of the maximal allowed scores for health problems such as foot pad dermatitis, the lowest value (reflecting the least impact on health) within the found range was chosen. By doing this, we may assume that the requirements have the least probability of negatively impacting the welfare of broilers.

To provide a complete overview of broilers' needs and requirements, a distinction was made between broilers with different growth rates. This distinction was based on the three most common types of broilers used in commercial poultry industry, namely fast, medium and slow growing broilers. Fast growing broilers reach their slaughter weight of two kg around 42 days of age, while medium growing broilers reach this weight around 56 days of age and slow growing broilers around 84 days of age. In Appendix II a list is given of all strains of fast, medium and slow growing broilers that were mentioned in literature. Although some gender differences exist in broilers which are mainly associated with growth rate, i.e. males growing faster than females (e.g. Bokkers and Koene, 2002), gender differences were not further discussed in the BoR as in general broiler chicks are not sexed prior to rearing in the Netherlands, and sexing is not provisioned to be a solution in design results of the overall project. Needs and requirements were furthermore discussed separately for four different age groups, which were divided into phase A (day 0 – 4 of age), phase B (day 4 – 14 of age), phase C (day 14 – 56 of age) and phase D (from day 56 of age until slaughter). During phase A chicks are ectothermic animals, i.e. they cannot regulate their own body temperature, with developing intestines that start to acquire foraging behaviour. During phase B chicks develop into endothermic animals, i.e. they are able to regulate their own body temperature, and further develop their foraging behaviour. During phase C chickens become fully endothermic and at the start of phase D the onset of puberty occurs. This distinction in crucial life phases was based on expert knowledge, and it was expected that at least some needs and requirements would differ between the different phases. Note that phase D does not apply to fast growing broilers, as these animals in general are slaughtered around the age of 42 days.

The literature search was performed using the library of Wageningen University and the internet. The online databases Scopus (www.scopus.com; not freely accessible, but available to employees of Wageningen UR) and Google Scholar (scholar.google.com; freely accessible) were used to search for literature using keywords. All keywords that have been used during this literature search are given in Appendix III. Main criteria for selection of literature were relevance of the topic studied, author(s), journal and year of publication, and language in which the study was written. Only studies in English and Dutch were included to prevent faults arising from translation. When data or conclusions from broiler studies were not sufficient to formulate the needs and requirements, this data was supplemented with data on laying hens or Jungle-fowl where applicable. For an objective and scientific approach during the formulation of the BoR, the conclusions reached in the report have been based on peer-reviewed scientific literature where possible. However, when insufficient peer-reviewed information was available on a particular subject, information taken from handbooks, expert opinions and practical knowledge of breeders or farmers was used to draw conclusions. The different types of references used for each statement in the BoR were described as originating from (1) peer reviewed literature, (2) grey literature, (3) expert opinion or (4) extension advice. When selecting grey literature of sufficient quality, the main criteria were status of author(s) and/or institutions that were linked to the publication, and the use of peer reviewed literature to support their conclusions. Extension advice was based on product sheets provided by breeding companies, and this information was merely used to supplement data on expected live body weights of broilers at different ages. To establish how physical health problems affect the behaviour of broilers a panel of international experts was asked to complete a survey, as there was a lack of peer reviewed literature on this topic. In this survey the effect of foot pad dermatitis, hock burn, aberrant gait and breast blisters on performance of different behaviours was assessed. The behaviours used in the survey were: forage (including locomotion, exploration, ground/litter scratching and pecking), feeding, drinking, rest on perch, rest on floor, preen, dust bathe and play. The scores used in this survey to assess the severance of these health problems are displayed in Table 1. As mentioned above, results of this survey were used according to the 'precautionary principle', i.e. taking the lowest score that any member of the panel had indicated as quantification for maximal allowed score for that health problem. In Appendix IV the survey is described in more detail.

Table 1 Scoring categories of four physical health problems as used in expert opinion survey on the influence of health problems on behaviour of broilers. Scoring categories and descriptions were taken from the work of Kestin and colleagues (1992) and the Welfare Quality® assessment protocol for broilers (Welfare Quality, 2009).

Health Problem	**Scoring Categories**	**Explanation**
Foot pad dermatitis	A,B,C	A: No visible food pad dermatitis B: Minimal evidence of foot pad dermatitis C: Clear evidence of foot pad dermatitis
Hock burn	A,B,C	A: No visible hock burn B: Minimal evidence of hock burn C: Clear evidence of hock burn
Gait	0,1,2,3,4,5	0: No abnormalities in gait 1: Slight abnormality in gait, without clear causation 2: Clear abnormality in gait, but chicken is able to move when necessary 3: Clear abnormality in gait, ability to move is severely reduced 4: Severe abnormality in gait, chicken can move only with great difficulty and will only walk when very motivated or when driven 5: Extremely severe abnormality in gait, chicken is incapable of sustained walking
Breast blister	0,1	0: No breast blister present 1: Breast blister present

3 Needs and Requirements of Broilers

The needs and requirements of broilers as discussed in the BoR have been divided into three categories, namely behaviour, health and nutrition. Each need was coded with a two-letter code. The list shown below gives an overview of all identified needs and additional information is provided for each need in the following sections.

Behavioural needs:
FO = Foraging and Exploration
RE = Rest and Sleep
SU = Sun bath
PR = Preen
DU = Dust bath
WI = Wing and Leg Stretch
SO = Social Interaction and Play

Health related needs:
AE = Aerial environment
TH = Thermal environment
MI = Microbial environment
SP = Spatial environment

Nutritional needs:
FE = Feed and Water Intake

3.1 Behavioural Needs

Domestic fowl exhibit several behavioural patterns reminiscent of the behaviour of their ancestors, the Jungle-fowl (Dawkins, 1989; Duncan, 1998). In broilers most of these behaviours can still be observed, although activity levels vary between strains with different growth rates (e.g. Bizeray et al., 2000; Bokkers and Koene, 2003a; Branciari et al., 2009). Each type of behaviour requires particular features in the environment (Duncan, 1998). Spatial requirements for instance can differ per behaviour. In addition to the absolute space requirement necessary to perform the behaviour, chickens prefer to stay close to conspecifics while performing particular behaviours (e.g. preening), while for other behaviours they prefer larger inter-individual distances (Keeling, 1995). Note that for the quantification of spatial requirements in the BoR it was decided to leave out any quantifications regarding height requirements, if the height required would not exceed the height of the broiler. This leads to quantifications given in area (length x width) instead of space (length x width x height).

Individual spatial requirements aside, it seems that broiler welfare is more affected by stocking densities than pen size per se (Leone and Estevez, 2008; Leone et al., 2010) which was also found in a study in which broilers were willing to work for access to pens with lower densities (Buijs et al., 2011). Furthermore several behaviours are performed in synchronisation, i.e. simultaneously, with conspecifics, such as feeding, foraging, resting, and preening (Alvino et al., 2009b), and this should also be taken into account when determining spatial requirements for groups of broilers. Another important aspect of the broilers' environment is the amount of shelter it offers, which is thought to be important for protection against predators or to avoid disturbances by conspecifics (Cornetto and Estevez, 2001; Buijs et al., 2010). Below some additional remarks are given for each category of behavioural needs discussed in the BoR.

3.1.1 Foraging and Exploration

Chickens in general show two daily peaks in foraging behaviour, with one peak occurring shortly after the onset of lighting and the second at the end of the light period (Savory, 1980; Lee and Chen, 2007). However, this diurnal distribution flattens when light intensity during the light period, i.e. photophase, is comparable to the light intensity during the dark period, i.e. scotophase (Alvino et al., 2009a). When fed only concentrated feed it is possible that even though the broiler has fulfilled its nutritional needs, the behavioural need for foraging is not yet satisfied. The animal will then continue to exhibit behaviour associated with foraging, such as exploration, ground scratching and ground pecking (Hughes and Duncan, 1988; Jensen and Toates, 1993). The time broilers spend on foraging gradually decreases with age, most likely due to a decrease in mobility caused by their high body weights (Bizeray et al., 2002ab; Bokkers and Koene, 2003a; Bessei, 2006) but not a decrease in motivation (Weeks et al., 1994; Bokkers and Koene, 2002, 2004; Bokkers et al., 2007). Furthermore, in modern husbandry practices broilers are prone to develop contact dermatitis and skeletal or metabolic disorders, such as leg weakness or ascites, which further compromises their mobility (Bessei, 2006). Decreases in mobility, and overall activity, are more pronounced in fast growing broilers than in medium or slow growing broilers, which is likely the result of differences in growth rate and body size (Bokkers and Koene, 2003a). Thus, although broilers seem to have a need to perform foraging behaviour they are limited in their ability to forage due to their size and potential health problems. To enable these chickens to perform foraging behaviour even though they are less mobile, it is important to present them with a suitable environment, providing for instance appropriate foraging substrate, sufficient space, sufficient lighting and so on as described in the BoR.

3.1.2 Rest and Sleep

The function of rest in poultry is assumed to be similar to the function of rest in mammals, namely physiological recuperation of the body (Blokhuis, 1983; Malleau et al., 2007). Two forms of resting are distinguished in the BoR, namely resting during the photophase (hereafter called resting), and resting during the scotophase (hereafter called sleeping). Quality of resting is influenced by housing conditions such as lighting regime, i.e. length of photophase and scotophase (Bessei, 2006; Malleau et al., 2007), space availability (Alvino et al., 2009b) and quality of the substrate (Ekstrand et al., 1997; Bessei, 2006). Synchronisation of resting and sleeping is high when the environment permits this (Kristensen et al., 2004), especially in young broilers. In contrast with other domestic fowl, broilers do not appear to be very motivated to perch while sleeping (LeVan et al., 2000; Pettit-Riley and Estevez, 2001), although this could be caused by inconveniently constructed perches, high body weight and/or lack of mobility rather than lack of motivation (Bokkers and Koene, 2003a). Time spent resting increases as broilers grow older, which is thought to be another consequence of increased body size and decreased mobility (Weeks et al., 1994, 2000; Bokkers and Koene, 2003a). It is thus important to provide broilers with comfortable resting and sleeping places, both at and above ground level, to prevent disturbances during resting or sleeping as well as development of health problems after prolonged periods of inactiveness, such as foot pad dermatitis (Bessei, 2006).

3.1.3 Sun Bath

Although the function of sun bathing has not been studied extensively, chickens are known to take sun baths. Possible functions of sun bathing are synthesis of vitamins (Lewis and Gous, 2009), uptake of warmth and removal of parasites although no scientific evidence for the latter two functions has been reported. In laying hens sunlight furthermore appears to function as a means for orientation (Zimmerman et al., 2009), but it is not known whether broilers utilise sunlight in a similar fashion.

3.1.4 Preen

Feather condition is optimised by preening and dust bathing. During preening, fowls use their beak to rearrange and smooth their feathers while distributing an oily secretion from the uropygial gland onto the plumage. This secretion helps to maintain feather condition by waterproofing the plumage, and it acts as an antimicrobial agent (Sandilands et al., 2004). Time spent on preening is reduced in broilers with decreased mobility, possibly due to chronic pain experienced by these birds (Weeks et al., 2000). However, it has also been observed that frustrated chickens show displacement preening (Duncan and Wood-Gush, 1972), which in contrast could lead to an increase in preening in less mobile broilers (Bokkers and Koene, 2003a). Note however that this increase was found for fast growing broilers when time spent on preening during the first six weeks of life was compared to time spent on preening during weeks seven to twelve of age (Bokkers and Koene, 2003a) and this situation differs from commercial practice in which these broilers are kept for six weeks instead of twelve.

3.1.5 Dust Bath

Domestic fowl show a diurnal dust bathing rhythm which peaks around six hours after the onset of photophase (Vestergaard, 1982). Dust bathing serves to maintain the plumage and its thermo-insulating properties (Jensen and Toates 1993), and broilers prefer to dust bath in material that is dry, loose and contains fine particles, such as sand or peat dust (Arnould et al., 2004; Shields et al., 2004, 2005). This material is used to remove excess feather lipids (Van Liere, 1992) and inadequate dust bathing substrate or deprivation of dust bathing can lead to reduced thermo-insulation (Jensen and Toates 1993).

3.1.6 Wing and Leg Stretch

Stretching of wings and legs, and wing flapping are considered to be comfort behaviours, i.e. functioning to stretch muscles and improving physical comfort (Nicol, 1989). Broilers should be provided with sufficient space to perform these behaviours.

3.1.7 Social Interaction and Play

Broilers are social animals that perform several behaviours in synchronisation with their neighbours. For such social interactions to occur it is important that the provided lighting is of sufficient intensity, to enable visibility of the surrounding (Alvino et al., 2009b). Furthermore, since broilers are young animals, they should be have enough space to perform play behaviour. Play behaviour seems to occur mainly before and during puberty, which starts around 56 days of age in male chicks, and relates to the development of behaviours that are important for survival in feral fowl. However, for broilers some of these behaviours have become irrelevant due to their short life span. One form of play behaviour is running around without any apparent reason or causation, which is often observed in young chickens (e.g. ASG, 2010). This behaviour might not purely be play behaviour, but might simply function to stretch and exercise limbs. When chickens get older or when stocking density increases, the frequency of running decreases (ASG, 2010). It is however unclear whether this decrease is caused by a decreased motivation to run, or decreased mobility.

The play behaviour of male chicks in puberty shows some resemblance to fighting and is regarded as the precursor of sexual behaviour, which starts around 70 days of age with crowing calls. Development of agonistic behaviour, which can no longer be regarded as play behaviour, takes place between six and twelve weeks of age (Mench, 1988), although prevalence of agonistic behaviour is low in broilers (e.g. Mench, 1988; Estevez et al., 1997; Pettit-Riley et al., 2002).

3.2 Health Related Needs

It is intuitively known that maintenance of good health, i.e. absence of disease and good physical condition, is important for the welfare of broilers. Fulfilment of needs discussed prior in this report, such as foraging and preening, can directly or indirectly contribute to the health status of an animal. However, also environmental factors can influence animal health. It was decided to include such environmental factors in this BoR, in order to give a complete overview of factors acting on the welfare status of broilers.

3.2.1 Aerial Environment

The quality of air is important since broilers utilise pulmonary respiration for their oxygen supply, and poor air quality can have detrimental health effects (Lai et al., 2009). Air quality is affected by the amount and size of dust particles present (Takai et al., 1998), and the concentration of several gaseous substances commonly present in poultry stables such as ammonia or carbon dioxide (ASG, 2004). The air within a confined space should be refreshed regularly to prevent loss of quality that could lead to respiratory problems. Furthermore the condition of floor-covering substrate, if this is present, should be maintained properly, as substrate is an important source of dust, gasses such as ammonia, and potentially pathogenic micro organisms (Takai et al., 1998; Wathes et al., 2002; Carey et al., 2004; Lacey et al., 2004; Young et al., 2009).

3.2.2 Thermal Environment

Relative humidity and ambient temperature, both of air and objects, can have a major influence on broilers' welfare as they play an important role in the thermoregulation of the animal (Dawkins et al., 2004; Lin et al., 2005ab). When related to stocking density, the detrimental effects of stocking density are aggravated when relative humidity and/or ambient temperature exceed maximal recommended values (Dawkins et al., 2004; Jones et al., 2005).

3.2.3 Microbial Environment

Diseases caused for instance by viral or bacterial infections impair the health, and thus welfare, of animals (Broom, 2006). Several infections are known to occur in broiler husbandry (Young et al., 2009), such as infections with *Campylobacter* ssp. (e.g. Rushton et al., 2009), *Eimeria* ssp. (e.g. McDonald and Shirley, 2009) or *Salmonella* ssp. (e.g. Heyndrickx et al., 2002; Toscano et al., 2010). It is advised to restrict exposure to pathogens that could induce these infections. Furthermore broilers should be able to develop a good functioning immune system to fight off infections without experiencing detrimental health effects. Exposure to severe acute stress should be minimised and chronic stress should be absent as stress impairs welfare (Shini et al., 2010). In this regard, also husbandry practices such as toe trimming or beak trimming should be banned, as these procedures could for instance induce chronic pain (e.g. Jendral and Robinson, 2004).

3.2.4 Spatial Environment

The spatial environment can be defined as the sum of all elements contained in the space in which broilers are kept, including feeding and drinking places, any substrate present, perches and so on. Cognitive stimulation arises from the spatial environment, and the amount of cognitive stimulation that is experienced by an animal depends on the composition of its spatial environment. It can be argued that cognitive stimulation by the environment might be a need for broilers, even though no scientific studies on this topic were available. In nature, it is important to learn from the environment which places are safe, which insects or plants can be eaten, where drinking water can be found and so on. The surroundings in a broiler pen usually differ largely from nature as conditions in a pen are largely controlled and kept constant, while nature is dynamic. Both situations have advantages and disadvantages. A controlled environment is safer for the animal, with regard to for instance predators or pathogens, but might deprive a broiler of environmental stimuli. Although the possible detrimental effects of such a low-stimulus surrounding are still unknown for broilers, such detrimental effects have been found for other animals, such as laying hens (e.g. Pohle and Cheng, 2009; Dixon et al., 2010), pigs (e.g. Stewart et al., 2008; Munsterhjelm et al., 2009), horses (e.g. Wickens and Heleski, 2010) and rats (e.g. Abou-Ismail et al., 2010; Harris et al., 2010). Even though broilers have a relatively short life-span, it cannot be excluded that deprivation of environmental stimuli has a detrimental effect on the welfare of broilers.

3.3 Nutritional Needs

The intake of feed and water is important for broilers to survive and grow. It is advised to supply broiler chicks with food and water directly post hatch to prevent dehydration and starvation (e.g. Van de Ven et al., 2009), although this is often not practiced in commercial hatcheries (Careghi et al., 2005). During its growing period, a broilers demand for specific nutrients fluctuates over time. A relatively low energy diet with high crude protein content is important during fast growth early in life, while later on their dietary preference shifts to a high energy diet with low crude protein content (Quentin et al., 2005). Since the growth rate of fast growing broilers is higher than that of medium or slow growing broilers, their protein requirement will also be higher during the first weeks post-hatch (Morris and Njuru, 1990). However, besides nutritional composition, the form in which feedstuff is taken up is also important during growth. Development of the chickens' digestive system is influenced by particle size of the feed, with larger particles stimulating gastric functions such as secretion of digestive enzymes. Besides aiding in feed digestion, these enzymes are beneficial for the prevention of intestinal colonization by feed-borne pathogens (Engberg et al., 2002).

4 Discussion and Conclusion

During the formulation of the BoR it became clear that even though studies on broiler growth rate and feed conversion ratio are numerous, broiler health and welfare have been studied less extensively. Even though it was possible to verify most needs, for some other needs it was necessary to resort to literature on domestic fowl or laying hens, or to grey literature. However for a few needs it could only be intuitively argued that they are valuable for the broiler, even though no scientific evidence was available to support such a conclusion. For instance, it is common practice that broilers grow up without a broody hen present. In natural situations, a broody hen provides protection, food and warmth. Under commercial circumstances these tasks become irrelevant, but it is unclear if and how deprivation of their mother negatively affects welfare of broiler chicks (Riber et al., 2007). Furthermore, it is unclear if broilers would need or benefit from 'being outside' or, more specifically, from a surrounding which represents (to some extent) their natural environment, including different types of vegetation, natural light, insects and so on. Clearly broilers are able to function in a controlled, stimuli-poor environment, but it is unknown what the possible direct and indirect detrimental effects of such an environment are.

Further scientific research is necessary to formulate more concise requirements, or to understand the physiological and behavioural mechanisms behind several needs identified in the BoR. For instance, peer reviewed publications on space requirements for broilers while performing active behaviours, such as foraging, preening and dust bathing, could not be found in literature. Furthermore, the importance of play behaviour in young broilers, as well as sun bathing, as discussed in this report has been largely based on speculation and expert knowledge, as no peer reviewed studies were available. Some peer reviewed literature was available on the topic of perching in broilers, but most studies reported very little perching (e.g. LeVan et al., 2000; Pettit-Riley and Estevez, 2001), although it is possible that the utilised perches were not ideal for usage by broilers, for instance due to small perch diameter or shape of the perches. It would be interesting to study for instance the influence of perch design and perch height on perching behaviour in broilers, to determine if broilers are indeed not motivated to perch or perhaps restricted in their behaviour due to environmental constraints and/or decreased mobility. Finally, the differences between fast, medium and slow growing broilers with regard to their needs and requirements require more study, in order to optimise the environment for the type of broiler that is kept. It should be kept in mind that required housing conditions for slow growing broilers could be different from housing conditions for fast or medium growing broilers and vice versa.

In this BoR an overview of the needs and requirements of fast, medium and slow growing broilers is presented. Even though no rating of the importance of specific needs is given here, it can be argued that some needs are likely to have more influence on the welfare of broilers than others. In the future such rating of needs and requirements could be accomplished following the examples of the Overall Welfare Assessment procedure (Bracke et al., 1999b), the Fowl Welfare Model for laying hens (De Mol et al., 2004), or the Welfare Quality® assessment protocol (Welfare Quality, 2009), but that is beyond the scope of this report. However some speculation can be done here regarding the relative importance of the different needs. The ability to perform natural behaviour, especially foraging, preening and dust bathing, seems to be important to prevent frustration. However in conventional poultry husbandry systems space requirements to perform these behaviours are often not met, especially during the final phase of the rearing period when broilers are close to their finishing weight. Additionally, health problems such as contact dermatitis or leg weakness can severely limit a broiler in its mobility. To ensure good welfare, it deems necessary to provide a broiler minimally with sufficient space and a clean environment.

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Appendices

Appendix I: Glossary

Breast blister	Blisters underneath the skin overlying the keel bone, caused by contact dermatitis
Broiler, fast growing	Strain of chicken utilised for meat production that reaches its slaughter weight at around six weeks of age
Broiler, medium growing	Strain of chicken utilised for meat production that reaches its slaughter weight at around eight weeks of age
Broiler, slow growing	Strain of chicken utilised for meat production that reaches its slaughter weight at around twelve weeks of age
Contact dermatitis	Inflammation of the skin caused by prolonged contact with irritating substance
Dust bathing	Cleaning plumage by moving around in substrate containing small particles, such as sand or peat dust
Endotherm	An animal that is able to maintain a constant body temperature independent of the environment
Ectotherm	An animal whose regulation of body temperature depends on external sources
Feed conversion ratio	Measure of efficiency with which feed is converted into body mass
Foot pad dermatitis	Contact dermatitis on the foot pad
Foraging	All behaviours involved in feed intake, such as ground scratching, ground pecking and consuming feedstuff
Hock burn	Contact dermatitis on the caudal part of the hock joint
Gait score	Scoring method used to evaluate severity of leg problems by assessing walking ability
Growth rate	Amount of weight gained within a specified period
Inhalable dust	Dust particles that enter the nose and mouth during normal breathing, with particle size of PM100 or less
Lateral recumbent lying space	The space an animal needs to move between standing and lying and vice versa
Leg weakness	Common name for leg problems with different causes
Metabolisable energy	Fraction of energy intake that can be used for maintenance, growth and production, which can be calculated as the difference between gross energy intake and gross energy loss from excreta
Photophase	Portion of day when natural light is available and/or artificial lighting is switched on
PM2.5 / PM100	Particulate matter, used to indicate particle size of dust particles

	present in the air. PM2.5 indicates a particle size of 2.5 μm, and PM100 indicates a particle size of 100 μm
Preening	Grooming of plumage by using the beak to distribute an oily secretion of the uropygial gland onto the feathers and to smooth the plumage
Respirable dust	Dust particles that penetrate into the gas exchange region of the lungs when inhaled, with particle size of PM2.5
Scotophase	Portion of day when no natural light is available and artificial lighting is switched off
Social facilitation	Event in which expression of a certain behaviour is induced by observation of other birds expressing that behaviour
Stocking density	Measure of the population size within a confined area, expressed in number of animals per m^2 or kg live weight per m^2
Synchronisation	Simultaneous performance of a certain behaviour by two of more animals
Thermoneutral zone	Range of environmental temperature range in which an animal is comfortable, because its basal rate of heat production is in equilibrium with rate of heat loss to the environment
Wing and leg stretch	Stretching of muscles to stimulate circulatory system and increase physical comfort; also known as comfort behaviour

Appendix II: Overview of Broiler Strains Found in Literature

In literature a large range of different strains of fast growing, medium growing and slow growing broilers is described. This table gives an overview of the different strains encountered during the literature review for this BoR and report.

Table 2:

Fast growing broilers	**Medium growing broilers**	**Slow growing broilers**
Ross 308	Kabir	Label Rouge/Poulet Fermier
Ross 708	Redbro	El-Salam
Ross PM3	I 457	Poulet Fermier du Piedmont/Redbro Cou Nu
Cobb 500	Cobb Sasso 150	ISA S 257
Cobb 700	Hubbard Pac JA	Ardennaise
Cobb Avian 48	Hubbard JA 957	Gline de Touraine
Arbor Acres Plus	Hubbard JA 757	Hubbard I 657
Hubbard Classic	Hubbard Gris Barré M / Gris Barré M Cou Nu	Hubbard Red JA / Red JA Cou Nu
Hubbard JV	Hubbard Redbro M / Redbro M Cou Nu	Three Yellow
Hubbard Flex	Hubbard New Hampshire M	Hubbard S 757 N
Hubbard F15	Hubbard Master Gris (Grey) M	Hubbard S 757
Hubbard Ultra-Yield	Hubbard Redpac M	Hubbard S 666
Lohmann Meat	Hubbard Gris Barré S / Gris Barré S Cou Nu	Hubbard S 68
I 957	Hubbard Redbro S / Redbro S Cou Nu	Hubbard Gris Barré (Grey Barred) JA / Gris Barré JA Cou Nu
Ross 508	Hubbard New Hampshire S	Gourmet Black
I 757	Hubbard Master Gris S	Gushi
Ross YAxPM3	Hubbard Redpac S	White Sussex
	I 657	White Dorking
		Ixworth
		Light Sussex
		Hubbard JA 657

Appendix III: Keywords for Literature Search

The following keywords were entered in Scopus and Google Scholar to find relevant literature. Note that not all combinations made with these words are given here, but only an enumeration of all keywords used during the literature search.

Keywords used:
Chicken, fowl, poultry, layer, laying hen, Jungle-fowl, Jungle fowl, broiler, slow, medium, fast, growth rate, behaviour, behavior, free choice, feed, food, size, pellet, particle, preference, color, colour, feeding, light, lighting, spectrum, intensity, lux, lx, flicker, sensitivity, frequency, incandescent, thermoneutral, temperature, cold stress, heat stress, width, height, length, size, body, space, area, surface allometric, allometry, body composition, space allowance, time, budget, allocation, activity, night, preen, function, comfort, preening, fowl, optimum space allocation, stocking density, physical space, social space, social facilitation, consumer demand, dust bath, dust bathing, dustbath, dustbathing, forage, foraging, explore, exploration, locomotion, sun bath, sun bathing, sunbath, sunbathe, sunbathing, sun, bask, basking, stretch, stretching, leg, wing, flap, flapping, social facilitation, synchronization, synchronizing, synchronisation, synchronising, synchrony, substrate, litter, floor, mother, maternal, imprint, imprinting, scotophase, scotoperiod, photophase, photoperiod, day length, daylength, label rouge, volwaard, vol waard, sun light, sunlight, rest, sleep, resting, sleeping, perch, perching, hierarchy, group, conspecifics, social, social interaction, play, recognition, hatch, patio, dark brooder, stereotypic behaviour, stereotypes, enrichment, mice, rat, minks, pigs

Appendix IV: Expert Opinion Survey

The following text was sent to several international experts in the field of broiler behaviour. They were approached by email to ask them to participate in the survey on influence of health problems on behaviour. Eight experts were approached, of which five agreed to participate.

"Dear colleague,

We would like to ask for your collaboration in a short survey for the project "Tasteful Broilers" (in Dutch: "Pluimvee met Smaak"), that is currently carried out by Wageningen UR Livestock Research and is commissioned by the Dutch government. As part of this project we aim to formulate an expert opinion on the effect of leg problems, dermatitis and breast blisters on the behaviour of broilers. This expert opinion will be included, together with numerous other aspects concerning the welfare of broilers, in a brief of requirements for the commercial broiler industry. You can find more information on this project at http://www.pluimveemetsmaak.wur.nl/ .

We ask for an expert opinion on the behavioural problems that can arise when broilers suffer from leg problems, dermatitis and/or breast blisters. Examples of occurring behavioural problems are when broilers perform a behaviour less often, less extensively or in a different manner. In the short survey, which is attached to this email as an Excel-file, we ask you to formulate according to some standardized and widely accepted score methods in which case the impaired health of a broiler would cause behavioural problems. In the Excel-file you will find the survey and a short explanation of the score methods. The survey is formed in such a way that answering the questions can be done quickly, by choosing your answer from the options given in a dropdown menu for each question. When you have filled in your answers, you can just return your Excel-file to us. The results of this survey will be incorporated anonymously in our brief of requirements, and we will send you a copy of the results in return for your cooperation. For your information we have furthermore included a list of colleagues that we have contacted for this survey, however the actual participants will remain anonymous and will not be named in any publication of this project. Thank you in advance for your participation, this is greatly appreciated!"

In the survey the participants were asked to indicate at which level of injury a certain health problem would affect performance of several behaviours. The behaviours included were: foraging (including locomotion, exploration, ground/litter scratching and pecking), feeding, drinking, rest on perch, rest on floor, preen, dust bathe and play. The health problems included were: foot pad dermatitis, hock burn, irregular gait and breast blisters. The severity of these health problems can be assessed according to standardized scales (e.g. Kestin et al., 1992; Welfare Quality, 2009), and a similar scaling was used here to indicate the level of injury arising from the health problems. This scaling was: for foot pad dermatitis and hock burn from A to C, with A indicating no abnormalities and C a severe health problem; for gait score from 0 to 5, with 0 indicating a normal gait and 5 extremely severe gait abnormalities; and for breast blisters from 0 to 1, with 0 indicating no breast blister present and 1 indicating presence of a breast blister.

Appendix V: Definitions and categories used in the Brief of Requirements of the Broiler (Hoeks et al. 2011)

Types of broilers:	
1) Fast growing: 2 kg at ≤42 days of age *)	*) currently, many broilers in these category already reach 2 kg at 32-35 days
2) Medium growing: 2 kg at ca. 56 days of age	
3) Slow growing: 2? Kg at 84 days of age	

Life stages: based on fast growing broilers		
Phase	Age (days posthatch)	Characterised by
A	0-4	ectotherm, development intestinal functioning, acquiring foraging behaviour
B	4-14	transition to endotherm, acquiring foraging behaviour
C	14-56	endotherm
D	56-eind	start of puberty

Life stages for different feeds used by nutrition companies: based on fast growing broilers (Handboek Pluimveehouderij 2004, p. 131)		
Phase	Age (days posthatch)	Characterised by
1: starter	0-14	very high growth rate, development intestines and feathering; concentrated feed with unsaturated short-chain fats, high in AA, low in undigestible proteins; small pellet size. Moderate energy and high crude protein content
2: grower	14-30	different growth with more fat deposition; feed with higher energy content from long-chain and saturated fats, lower AA content; larger pellet size. High energy and low crude protein content
3: finisher	30-end	lowest growth rate, prevention of fattening; lower protein and AA content but same energy content as phase 2

Heading	**Explanation**
Code	code used to indicate categories of needs
Need	need can not be fulfilled
Specification_Need	specification of subcomponents of a need, and attribution of these components to general need
Requirement	(NL: eis) requirement for the fulfillment of a (subcomponent of a) need
Life_stage	different life stages of broilers, see other table
Quantification_general	quantification of the requirement, specified for broilers or fowls in general
Quantification_fast	quantification of the requirement, specified for fast growing broilers
Quantification_medium	quantification of the requirement, specified for medium growing broilers
Quantification_slow	quantification of the requirement, specified for slow growing broilers
Explanation	additional explanation of need, requirement and/or quantification
Reference_peerreviewed	full reference of peer-reviewed articles used to determine need, requirement or quantification
Reference_greyliterature	quantification
Reference_expertopinion	additional information on expert opinion used to determine need, requirement or quantification
Reference_extensionadvice	additional information on extension advice (?) used to determine need, requirement or quantification
Reference_practicalexperience	additional information on practical experience used to determine need, requirement or quantification

List of breeds of different types of broilers (incomplete)		
Fast growing	*Medium growing*	*Slow growing*
Ross 308	Kabir	Label Rouge/Poulet Fermier
Ross 708	Redbro	El-Salam
Ross PM3	I 457	Poulet Fermier du Piedmont/Redbro Cou Nu
Cobb 500	Cobb Sasso 150	ISA S 257
Cobb 700	Hubbard Pac JA	Ardennaise
Cobb Avian 48	Hubbard JA 957	Gline de Touraine
Arbor Acres Plus	Hubbard JA 757	Hubbard I 657
Hubbard Classic	Hubbard Gris Barré M / Gris Barré M Cou Nu	Hubbard Red JA / Red JA Cou Nu
Hubbard JV	Hubbard Redbro M / Redbro M Cou Nu	Three Yellow
Hubbard Flex	Hubbard New Hampshire M	Hubbard S 757 N
Hubbard F15	Hubbard Master Gris (Grey) M	Hubbard S 757
Hubbard Ultra-Yield	Hubbard Redpac M	Hubbard S 666
Lohmann Meat	Hubbard Gris Barré S / Gris Barré S Cou Nu	Hubbard S 68
I 957	Hubbard Redbro S / Redbro S Cou Nu	Hubbard Gris Barré (Grey Barred) JA / Gris Barré JA Cou Nu
Ross 508	Hubbard New Hampshire S	Gourmet Black
I 757	Hubbard Master Gris S	Gushi
Ross YAxPM3	Hubbard Redpac S	White Sussex
	I 657	White Dorking
		Ixworth
		Light Sussex
		Hubbard JA 657

Overview of fowl welfare arranged according to the animal's main control systems, i.e. needs (Duncan, 1998; Anonymous, 2001)	
Needs	**Keywords**
Food and foraging	pecking and ground scratching requires litter or other foraging material and a variety of food items
Water	drinking, many times but generally not at night, overdrinking can lead to wet droppings and associated health risks; drinking is learned by pecking at glinstering drops of water
Rest	close together, perching (facilitated by exposure in ontogeny), mainly during the night
Thermoregulation	rest, raise feathers (cold), lift wings, panting (hot)
Respiration	limited capacity in broilers leading to ascites and sudden death
Health	E. coli, coccodiosis, roundworms (contact with manure), mites, leg weakness, bone fractures, fatty liver hemorrhagic syndrome, eye abnormalities (from low lighting or continuous lighting)
Social contact	peck order, communication, social recognition, social preferences, possibilities of escape, relatively small groups with one (dominant) cock, genetic variation in sociality
Mating	mating (damage), genetic variation in mating success
Nesting	nesting and egg laying behaviour, gakel call
Maternal	brooding, raising chicks
Exploration	pecking and scratching, visual investigation, deprivation may result in stereotypies (stereotyped pacing), feather pecking, fear
Safety/response to predators	perceived threat leads to fear, hysteria, alarm vocalization, intense or prolonged fear can cause injury and reduce livestock performance, chickens are agoraphobic and benefit from the provision of cover in open spaces, neophobia limits acceptance of novel food or resources, frustration, gakel call, aggression, group size
Movement/locomotion	lack of movement, bone atrophy
Body care/comfort/maintenance	preening, dust bathing, wing flapping, wing or leg stretching, raising and ruffling feathers, head shaking, head scratching, tail wagging, bill wiping

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
Forage & Exploration (FO)							
FO1	**Space**	*Area for forage-related exploration*	A				No data on cross sectional area occupied per chicken was found for this age.
FO2			B	Maximal stocking density 30-40 animals/m^2 (ASG, 2010)			Stocking density of 40 animals/m^2 led to decrease in foraging behaviour, i.e. ground scratching and ground pecking (both from standing or sitting position), when compared to a lower density (ASG, 2010). This likely indicates restrictions in ability to move as result of decrease in amount of space available per animal. No data on cross sectional area occupied per chicken was found for this age.
FO3			C	Recommended area: 909 cm^2/animal or 11 animals/m^2 or 27.2 kg/m^2; but see explanation			Range found for recommended maximal stocking density at end of growing period: 625 - 909 cm^2/animal or 11 - 16 animals/m^2 or 27.2 - 40 kg/m^2 when assuming that average weight at slaughter is 2.5 kg (Dawkins and Hardie, 1989; Hall, 2001). From these ranges the value providing the most space per animal was chosen as area recommendation to ensure that each broiler is always provided with sufficient space. Some evidence was found that a stocking density of 20 animals/m^2 would not compromise the behavioural freedom of the broilers up to day 21 of age (ASG, 2010), but as this study did not include stocking densities lower than 20 animals/m^2 it was decided not to include this data in the range given above. Cross sectional area was adapted from area given for adult laying hens (856 cm2/animal) with mean weight of 2.02 kg (Dawkins and Hardie, 1989); value was adapted for mean weight of 2.5 kg by using the formula: width of individual = 0.064*W^0.33 (Petherick, 2007; Petherick and Philips, 2009) to calculate body widths corresponding with weights of 2.02 kg and 2.5 kg. With the calculated body width for animals weighing 2.5 kg the cross sectional area for animals weighing 2.02 kg was adjusted. Laying hens differ in body morphology compared to broilers but it was assumed that this difference is caused by differences in body width and not body length. This adaptation was done to give an indication for the expected value for cross sectional area in broilers, but this value needs scientific validation. No data on cross sectional area occupied per chicken was found for broilers of this age.
FO4			D	Not applicable			No data on cross sectional area occupied per chicken was found for this age. Fast growing broilers are usually slaughtered at 42 days of age.
FO5		*Area occupied while in locomotion*	A				No data on cross sectional area occupied per chicken was found for this age.
FO6			B				No data on cross sectional area occupied per chicken was found for this age.
FO7			C	648.2 cm^2/animal or 15 animals/m^2 or 38.6 kg/m^2 (Bokkers et al., in press) but see explanation			Recommended area does not imply the distance covered during locomotion but only the area occupied by an animal when in locomotion. The area was calculated as the mean of values found for male (681.7 cm^2/animal) and female (614.6 cm^2/animal) broilers at six weeks of age (Bokkers et al., in press) as it is assumed that broilers are not sexed prior to rearing, leading on average to a 1:1 ratio of male and female broilers.
FO8			D	Not applicable			No data on cross sectional area occupied per chicken was found for this age.
FO9		*Linear surface for feeding*	all	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009)	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009)	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009)	This estimate of linear surface required per individual, i.e. width of an individual while feeding or drinking, does not take into account the effect of social behaviour on spatial requirements, such as competition for resources, which often require more space (Petherick, 2007; Petherick and Philips, 2009). Take into account that young broilers tend to sit in the feeder while feeding (when fed a concentrated feed from a feeder), until physical constraints (e.g. bars in feeder) make it impossible for them to do so and force them to reach the food from outside the feeder (Preston and Murphy, 1988). Older broilers often lie down during feeding (Weeks et al., 2000) which could cause a difference in occupied area. Abbreviations: W = live weight expressed in kg.
FO10		*Area for feeding*	A				No data on cross sectional area occupied per chicken was found for this age.
FO11			B				No data on cross sectional area occupied per chicken was found for this age.
FO12			C	Area occupied when feeding from standing position: 609.4 cm^2/animal or 16 animals/m^2 or 41 kg/m^2 (Bokkers et al., in press) Area occupied when feeding from sitting position: 615.2 cm^2/animal or 16 animals/m^2 or 40.6 kg/m^2 (Bokkers et al., in press)			Area was calculated as the mean of values found for male (653.8 cm^2/animal from standing position; 659.3 cm^2/animal from sitting position) and female (564.9 cm^2/animal from standing position; 571 cm^2/animal from sitting position) broilers at six weeks of age (Bokkers et al., in press) as it is assumed that broilers are not sexed prior to rearing, leading on average to a 1:1 ratio of male and female broilers.
FO13			D	Not applicable			No data on cross sectional area occupied per chicken was found for this age.

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
FO14		*Area for drinking*	A				No data on cross sectional area occupied per chicken was found for this age.
FO15			B				No data on cross sectional area occupied per chicken was found for this age.
FO16			C	Area occupied when feeding from standing position: 642.3 cm^2/animal or 15 animals/m^2 or 38.9 kg/m^2 (Bokkers et al., in press) Area occupied when feeding from sitting position: 615.2 cm^2/animal or 16 animals/m^2 or 40.6 kg/m^2 (Bokkers et al., in press)			Area was calculated as the mean of values found for male (687 cm^2/animal from standing position; 659.3 cm^2/animal from sitting position) and female (597.6 cm^2/animal from standing position; 571 cm^2/animal from sitting position) broilers at six weeks of age (Bokkers et al., in press) as it is assumed that broilers are not sexed prior to rearing, leading on average to a 1:1 ratio of male and female broilers.
FO17			D	Not applicable			No data on cross sectional area occupied per chicken was found for this age.
FO18	**Foraging material**	*Loose material*	all	Easy to move with feet or beak (Welfare Quality, 2009)	Easy to move with feet or beak (Welfare Quality, 2009)	Easy to move with feet or beak (Welfare Quality, 2009)	
FO19		*Edible particles*	A	Small edible particles (Hogan, 1984)	Small edible particles (Hogan, 1984)	Small edible particles (Hogan, 1984)	Chickens learn to associate pecking with feeding by pecking and subsequently ingesting particles during day 0-3, and are then able to distinguish between edible and non-edible items after day 3 (Hogan, 1984). Ideal size of particles is unknown but should correspond with size of beak (Portella et al., 1988).
FO20			BCD	Small edible particles (Hogan, 1984; Ekstrand et al., 1997)	Small edible particles (Hogan, 1984; Ekstrand et al., 1997)	Small edible particles (Hogan, 1984; Ekstrand et al., 1997)	Ideal size of particles is unknown but should correspond with size of beak (Portella et al., 1988).
FO21	**Light**	*Light of sufficient intensity*	all	200 lux (Davis et al., 1999; Prescott and Wathes, 2002)	200 lux (Prescott and Wathes, 2002)	200 lux (Prescott and Wathes, 2002)	Quantification is based on results of studies with fast growing broilers (Davis et al., 1999) as well as laying hens (Prescott and Wathes, 2002). It is assumed that broilers and laying hens have similar visual capacities and thus both prefer to feed in (relatively) well lit environments. This is in accordance with findings that synchronised foraging in broilers increases in sufficient lighting (Alvino et al., 2009).
FO22		*Light spectrum resembling daylight*	C	$400 < \lambda < 750$ nm (Kristensen et al., 2007)			
FO23		*Light frequency above flicker sensitivity treshold*	all	> 72 Hz (Jarvis et al., 2002)	> 72 Hz (Jarvis et al., 2002)	> 72 Hz (Jarvis et al., 2002)	Peak sensitivity for photopic flicker occurs around 15 Hz in adult laying hens, but is affected by light intensity. With light intensity of 40 lux the flicker sensitivity threshold for adult laying hens was measured at 71.5 Hz, and this threshold reduced at lower light intensities (Jarvis et al., 2002). It is assumed that flicker sensitivity in broilers is similar to that of laying hens.
FO24	**Time**	*Time spent foraging (% of photophase)*	A	22.5 - 35% (Bokkers and Koene, 2003; Malleau et al., 2007)		15.5 - 39% (Bokkers and Koene, 2003; Malleau et al., 2007)	Range given here includes all behaviours associated with foraging, i.e. ground scratching, ground pecking and consuming feedstuff. Foraging behaviour follows a diurnal pattern with an U-shaped distribution, with peaks in the beginning and end of photophase (Savory, 1980; Lee and Chen, 2007). When provided only with concentrated feed the behavioural need of foraging is often not fulfilled after consumption of the feed. The chicken will then often continue to show foraging behaviour such as ground scratching and pecking even if no feed is present (Hughes and Duncan, 1988).
FO25			B	13 - 41% (Bokkers and Koene, 2003; Shields et al., 2005; Malleau et al., 2007)		10 - 44% (Bokkers and Koene, 2003; Malleau et al., 2007)	In the study of Shields and colleagues (2005) two types of bedding were used, namely sand and wood shavings. Time budgets mentioned here were taken from the results found for broilers housed on sand as this seemed to be favored above wood shavings, indicated by higher levels of activity in pens with sand bedding.
FO26			C	11.3 - 16.5% (Murphy and Preston, 1988; Weeks et al., 2000; Bokkers and Koene, 2003; Shields et al., 2005)		8.8% (Bokkers and Koene, 2003)	Time spent foraging typically decreases in time, presumably due to reduced mobility caused by high body weight, leg weakness and decrease in available space (Bizeray et al., 2002ab). In the study of Shields and colleagues (2005) two types of bedding were used, namely sand and wood shavings. Time budgets mentioned here were taken from the results found for broilers housed on sand as this seemed to be favored above wood shavings, indicated by higher levels of activity in pens with sand bedding.
FO27			D	Not applicable		9.3% (Bokkers and Koene, 2003)	
FO28		*Time spent drinking (% of photophase)*	A	2 - 8.5% (Bokkers and Koene, 2003; Malleau et al., 2007)		0.5 - 2% (Bokkers and Koene, 2003; Malleau et al., 2007)	
FO29			B	2 - 4% (Bokkers and Koene, 2003; Malleau et al., 2007)		0.5 - 3% (Bokkers and Koene, 2003; Malleau et al., 2007)	
FO30			C	3.4 - 4.7% (Murphy and Preston, 1988; Weeks et al., 2000; Bokkers and Koene, 2003)		1.8% (Bokkers and Koene, 2003)	

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
FO31			D	Not applicable		3.5% (Bokkers and Koene, 2003	
FO32	**Good physical health**	*Maximal allowed score for foot pad dermatitis*	all	A	A	A	Foot pad dermatitis score indicates the severity of contact dermatitis on the skin of the foot. Main cause of foot pad dermatitis is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of foot pad dermatitis at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was B, the highest score was C, and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Scores for only feeding/drinking (without other behaviours associated with foraging) ranged from C to > C. Classification of score: A = no evidence of foot pad dermatitis; B = minimal evidence of foot pad dermatitis; C = evidence of foot pad dermatitis (Welfare Quality, 2009 p.35).
FO33		*Maximal allowed score for hock burn*	all	A	A	A	Hock burn score indicates the severity of contact dermatitis on the skin of the caudal part of the hock joint. Main cause of hock burn is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of hock burn at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was B, the highest score was > C (i.e. behaviour is not likely to be affected by any degree of hock burn), and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Scores for only feeding/drinking (without other behaviours associated with foraging) ranged from C to > C. Classification of score: A = no evidence of hock burn; B = minimal evidence of hock burn; C = evidence of hock burn (Welfare Quality, 2009 p.35).
FO34		*Maximal allowed score for gait*	all	0	0	0	Gait score indicates how severely leg weaknesses affect walking ability. Five experts were asked to determine the gait score at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was 1, the highest score was 3, and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Scores for only feeding/drinking (without other behaviours associated with foraging) ranged from 2 to 4. In short, scores are classified as: 0 = no abnormalities in gait; 1 = slight abnormality in gait, without clear causation; 2 = clear abnormality in gait, but chicken is able to move when necessary; 3 = clear abnormality in gait, ability to move is severely reduced; 4 = severe abnormality in gait, chicken can move only with great difficulty and will only walk when very motivated or when driven; 5 = extremely severe abnormality in gait, chicken is incapable of sustained walking (Welfare Quality, 2009 p.34). For extensive descriptions of the different scoring categories defined in the gait scoring method, see Kestin et al. (1992).
FO35		*Maximal allowed score for breast blister*	all	1	1	1	Breast blisters are caused by contact dermatitis of the skin overlying the keel (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of breast blistes at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. All experts scored > 1 (i.e. behaviour is not likely to be affected by breast blisters). Score for only feeding/drinking (without other behaviours associated with foraging) was > 1. Classification of score: 0 = no breast blister; 1 = breast blister present (Welfare Quality, 2009 p.41).

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
Rest (RE)							
RE1	**Resting during photophase**	*Time*	A	42.4 - 68% (Bizeray et al., 2000; Bokkers and Koene, 2003; Malleau et al., 2007)		37.4 - 71% (Bizeray et al., 2000; Bokkers and Koene, 2003; Malleau et al., 2007)	In the middle of photophase resting is mostly done on the ground, while at the beginning and end of photophase and during scotophase resting on raised spaces is more common (Lee and Chen, 2007). * Rest is defined as: the animal is either sitting idle, i.e. "sitting with hocks resting on ground without any other activity", or lying, i.e. "[lying] with the head flat on the bedding or with the head under a wing either with eyes open or closed" (Bokkers and Koene, 2003). For comparison purposes it is assumed that the area occupied during sitting is equivalent to the area occupied during lying. 'Resting' indicates rest during photophase, and 'sleeping' indicates rest during scotophase.
RE2			B	15 - 79% (Bizeray et al., 2000; Bokkers and Koene, 2003; Shields et al., 2005; Kristensen et al., 2007; Malleau et al., 2007)		29 - 68% (Bizeray et al., 2000; Bokkers and Koene, 2003; Malleau et al., 2007)	In the study of Shields and colleagues (2005) two types of bedding were used, namely sand and wood shavings. Time budgets mentioned here were taken from the results found for broilers housed on sand as this seemed to be favored above wood shavings, indicated by higher levels of activity in pens with sand bedding. Large differences between studies might be caused by for instance usage of different observation methods, differences in experimental design or inter-observer differences.
RE3			C	20 - 78% (Murphy and Preston, 1988; Bizeray et al., 2000; Weeks et al., 2000; Shields et al., 2005; Bokkers and Koene, 2003; Kristensen et al., 2007)		30 - 60% (Bizeray et al., 2000; Bokkers and Koene, 2003)	In the study of Shields and colleagues (2005) two types of bedding were used, namely sand and wood shavings. Time budgets mentioned here were taken from the results found for broilers housed on sand as this seemed to be favored above wood shavings, indicated by higher levels of activity in pens with sand bedding.
RE4			D	Not applicable		37% (Bokkers and Koene, 2003)	
RE5		*Comfortable resting place*	all	Comfortable, clean and dry substrate (Ekstrand et al., 1997; Bessei, 2006)	Comfortable, clean and dry substrate (Ekstrand et al., 1997; Bessei, 2006)	Comfortable, clean and dry substrate (Ekstrand et al., 1997; Bessei, 2006)	Main causes of contact dermatitis are prolonged periods of sitting/lying on wet litter (Ekstrand et al., 1997; Bessei, 2006).
RE6		*Area for lying*	all	General estimate of space occupied per individual animal when lying: area (m^2) = 0.027 x $W^{0.67}$ (Petherick, 2007; Petherick and Philips, 2009). General estimate of lateral recumbent lying space of an individual animal: area (m^2) = 0.047 x $W^{0.66}$ (Petherick, 2007; Petherick and Philips, 2009)	General estimate of space occupied per individual animal when lying: area (m^2) = 0.027 x $W^{0.67}$ (Petherick, 2007; Petherick and Philips, 2009). General estimate of lateral recumbent lying space of an individual animal: area (m^2) = 0.047 x $W^{0.66}$ (Petherick, 2007; Petherick and Philips, 2009)	General estimate of space occupied per individual animal when lying: area (m^2) = 0.027 x $W^{0.67}$ (Petherick, 2007; Petherick and Philips, 2009). General estimate of lateral recumbent lying space of an individual animal: area (m^2) = 0.047 x $W^{0.66}$ (Petherick, 2007; Petherick and Philips, 2009)	Lateral recumbent lying space describes the space an animal needs to move between standing and lying and vice versa (Petherick, 2007). Formulas given here are general estimates, but can be used as indication for space requirements for broilers. No data on cross sectional area occupied per chicken was found for broilers. Abbreviations: W = body weight in kg.
RE7			C	636.2 cm^2/animal or 15 animals/m^2 or 39.3 kg/m^2 (Bokkers et al., in press) but see explanation			Range found for recommended maximal stocking density at end of growing period: 625 - 636.2 cm2/animal or 15 - 16 animals/m2 or 39.3 - 40 kg/m2 when assuming that average weight at slaughter is 2.5 kg (Hall, 2001; Bokkers et al., in press). From these ranges the value providing the most space per animal was chosen as area recommendation to ensure that each broiler is always provided with sufficient space. Cross sectional area was calculated as the mean of values found for male (667.2 cm^2/animal) and female (605.1 cm^2/animal) broilers at six weeks of age (Bokkers et al., in press) as it is assumed that broilers are not sexed prior to rearing, leading on average to a 1:1 ratio of male and female broilers.
RE8		*Light intensity*	AB	200 lux (Davis et al., 1999)			Light intensity indicated here is preferred light intensity during photophase (i.e. the light period). Young chicks prefer to sleep in relatively bright light during the day as opposed to older chickens. A possible reason for this could be that older chickens had learned to enter a particular environment to perform particular activities and thus that such learning required some time or occured later in life. Other explanations given by the authors were that young chicks were influenced by minor temperature differences between brightly lit or dimly lit compartments, although this seemed unlikely due to the design of this experiment, or an increase in fearfulness with age and thus a preference for a dimly lit environment (Davis et al., 1999).
RE9			CD	< 10 lux (Davis et al., 1999)			
RE10		*Light spectrum resembling daylight*	C	400 < λ < 750 nm (Kristensen et al., 2007)			

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
RE11		*Light frequency above flicker sensitivity treshold*	all	> 54 Hz (Jarvis et al., 2002)	> 54 Hz (Jarvis et al., 2002)	> 54 Hz (Jarvis et al., 2002)	Peak sensitivity for photopic flicker occurs around 15 Hz in adult laying hens, but is affected by light intensity. With light intensity of 8 lux the flicker sensitivity threshold for adult laying hens was measured at 54 Hz (Jarvis et al., 2002). It is assumed that flicker sensitivity in broilers is similar to that of laying hens.
RE12	**Good physical health**	*Maximal allowed score for foot pad dermatitis*	all	B	B	B	Foot pad dermatitis score indicates the severity of contact dermatitis on the skin of the foot. Main cause of foot pad dermatitis is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of foot pad dermatitis at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. Resting during photophase was defined as resting on ground. The lowest score indicated was C, the highest score was > C (i.e. behaviour is not likely to be affected by any degree of foot pad dermatitis), and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: A = no evidence of foot pad dermatitis; B = minimal evidence of foot pad dermatitis; C = evidence of foot pad dermatitis (Welfare Quality, 2009 p.35).
RE13		*Maximal allowed score for hock burn*	all	B	B	B	Hock burn score indicates the severity of contact dermatitis on the skin of the caudal part of the hock joint. Main cause of hock burn is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of hock burn at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. Resting during photophase was defined as resting on ground. The lowest score indicated was C, the highest score was > C (i.e. behaviour is not likely to be affected by any degree of hock burn), and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: A = no evidence of hock burn; B = minimal evidence of hock burn; C = evidence of hock burn (Welfare Quality, 2009 p.35).
RE14		*Maximal allowed score for gait*	all	0	0	0	Gait score indicates how severely leg weaknesses affect walking ability. Five experts were asked to determine the gait score at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. Resting during photophase was defined as resting on ground. The lowest score indicated was 1, the highest score was 3, and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). In short, scores are classified as: 0 = no abnormalities in gait; 1 = slight abnormality in gait, without clear causation; 2 = clear abnormality in gait, but chicken is able to move when necessary; 3 = clear abnormality in gait, ability to move is severely reduced; 4 = severe abnormality in gait, chicken can move only with great difficulty and will only walk when very motivated or when driven; 5 = extremely severe abnormality in gait, chicken is incapable of sustained walking (Welfare Quality, 2009 p.34). For extensive descriptions of the different scoring categories defined in the gait scoring method, see Kestin et al. (1992).
RE15		*Maximal allowed score for breast blister*	all	0	0	0	Breast blisters are caused by contact dermatitis of the skin overlying the keel (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of breast blistes at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. Resting during photophase was defined as resting on ground. The lowest score indicated was 1, the highest score was > 1 (i.e. behaviour is not likely to be affected by breast blisters) and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: 0 = no breast blister; 1 = breast blister present (Welfare Quality, 2009 p.41).
Sleep(RE)							
RE16	**Resting during scotophase**	*Sufficient length of scotophase*	all	> 4 hours in succession (Olanrewaju et al., 2006)	> 4 hours in succession (Olanrewaju et al., 2006)	> 4 hours in succession (Olanrewaju et al., 2006)	Provision of natural day length is probably best to prevent disturbance of biological rhythms. Insufficient length of scotophase (< 4 hours) can cause abnormal development of the chickens' eyes, such as bupthalmos, glaucoma, myopia and retinal degeneration (Cummings et al., 1986; Li et al., 1995), and length of scotophase is negatively correlated with mortality and gait scores by reducing early growth rate (Olanrewaju et al., 2006).
RE17	**Sleeping on branch-like resting place**	*Resting place above ground level*	all	Resting place should not be connected to or attached on the floor	Resting place should not be connected to or attached on the floor	Resting place should not be connected to or attached on the floor	Resting place should be above ground level with free space between perch and floor, making it possible for the broiler to fold its claws around it.

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
RE18		*Easily accessible resting place*	all	Maximal height difference to cross in one leap: 10 cm (Bokkers and Koene, 2003)		Maximal height difference to cross in one leap: 10 cm (Bokkers and Koene, 2003)	Broilers are motivated to perch (e.g. Bizeray et al., 2002a; personal observations E. Bokkers), but it is important to provide raised spaces at suitable heights to facilitate perching (Davies and Weeks, 1995). Perches at 10 cm were found to be accessible by both fast and slow growing broilers up to twelve weeks of age (Bokkers and Koene, 2003). Fowls are known to prefer to perch at the highest place available and divide lower resting places according to rank if not enough space is available at highest place (Anonymous, 2001; Schrader and Müller, 2009), but it is expected that broilers are less mobile and cannot reach very high perches. It is recommended to provide enough perching space for all animals to perch simultaneously, divided over at least two different heights (with recommended height difference of 10 cm between ground and lowest perch, and between each higher perch) to create escape opportunities when conflicts occur.
RE19		*Sufficient loading capacity*	A	> 0.1 kg/animal (Aviagen, 2007a,b; Ross, 2007)			Based on average weight of broiler at end of life stage, taken from productsheets of representative commercial breeds.
RE20			B	> 0.425 kg/animal (Aviagen, 2007a,b; Ross, 2007)			Based on average weight of broiler at end of life stage, taken from productsheets of representative commercial breeds.
RE21			C	> 2.6 kg/animal when grown until day 42 (Aviagen, 2007a,b; Ross, 2007)	> 2.3 kg/animal (Cobb-Vantress, 2010)		Based on average weight of broiler at end of life stage, taken from productsheets of representative commercial breeds.
RE22			D	Not applicable	>2.8 kg/animal when grown until day 63 (Cobb-Vantress, 2010)		Based on average weight of broiler at end of life stage, taken from productsheets of representative commercial breeds.
RE23	**Perches with branch-like shape**	*Appropiate diameter*	A				No data on diameter preference of broilers was found for this age.
RE24			B				No data on diameter preference of broilers was found for this age.
RE25			C				No data on diameter preference of broilers was found for this age.
RE26			D	Diameter: 4.5 - 5 cm (Muiruri et al., 1990; Struelens et al., 2009; Pickel et al., 2010)	Diameter: 4.5 - 5 cm (Muiruri et al., 1990; Struelens et al., 2009; Pickel et al., 2010)	Diameter: 4.5 - 5 cm (Muiruri et al., 1990; Struelens et al., 2009; Pickel et al., 2010)	Range given was preferred by adult laying hens (Struelens et al., 2009; Pickel et al., 2010) or adult broiler breeders (Muiruri et al., 1990). No data was found for preference of broiler chickens.
RE27		*Sufficient stability*	all	Material with sufficient friction (Pickel et al., 2010)	Material with sufficient friction (Pickel et al., 2010)	Material with sufficient friction (Pickel et al., 2010)	Broilers should be able to maintain their balance on the perch without effort (Duncan et al., 1992). Sufficient friction prevents slipping. No data on preferences of broilers, or any quantification for preferred skid resistance was found.
RE28		*Area for sleeping on perch*	A	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009) but see explanation	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009) but see explanation	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009) but see explanation	Width of individual is used here to calculate minimal perch length required per chicken. Laying hens seem to prefer an interindividual distance of 5 cm while perching (Sandilands et al., 2009), although it is unknown if the same applies to broilers. Chickens are motivated to perch simultaneously (Duncan et al., 1992) and if chickens are able to synchronise resting behaviour, interruptions while resting caused by other active chickens are less frequent (Alvino et al., 2009). Furthermore very young chickens would prefer to rest simultaneously under the wings of their mother if the mother was still present during the first 2-3 weeks of their life. Thus enough perching space should be available to enable all broilers to perch simultaneously. Abbreviations: W = live weight expressed in kg.
RE29			B	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009)	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009)	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009)	Width of individual is used here to calculate minimal perch length required per chicken. Abbreviations: W = live weight expressed in kg.
RE30			C	20.3 - 22.4 cm/animal (Bokkers et al., in press)	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009)	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009)	Range indicated for fast growing broilers is average width of fast growing broiler chickens aged six weeks. Width of individual is used here to calculate minimal perch length required per chicken. Abbreviations: W = live weight expressed in kg
RE31			D	Not applicable	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009)	Width of individual (in m.) = 0.064 x $W^{0.33}$ (Petherick, 2007; Petherick and Philips, 2009)	Width of individual is used here to calculate minimal perch length required per chicken. Abbreviations: W = live weight expressed in kg.

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
RE32		*Time spent on perches (% of photophase)*	A	8% (Bokkers and Koene, 2003)		13% (Bokkers and Koene, 2003)	Percentage of time spent on perches as observed during five observation rounds per day (instantaneous scan sampling) during photophase, which lasted 23 hours during the first three days and 18 hours on following days (Bokkers and Koene, 2003). Although it is known that fowls are motivated to rest on perches during the scotophase (e.g. Lambe and Scott, 1998; Olsson and Keeling, 2000), perching also occurs during the photophase, possibly as a means to decrease stocking density on the floor (Martrenchar et al., 2000). For broilers, no data was found on the frequency of perching during scotophase.
RE33			B	15% (Bokkers and Koene, 2003)		35% (Bokkers and Koene, 2003)	Percentage of time spent on perches as observed during five observation rounds per day (instantaneous scan sampling) during photophase, which lasted 18 hours per day (Bokkers and Koene, 2003).
RE34			C	24.5% (Bokkers and Koene, 2003)		38.7% (Bokkers and Koene, 2003)	Percentage of time spent on perches as observed during five observation rounds per day (instantaneous scan sampling) during photophase, which lasted 18 hours per day (Bokkers and Koene, 2003).
RE35			D	Not applicable		35.3% (Bokkers and Koene, 2003)	Percentage of time spent on perches as observed during five observation rounds per day (instantaneous scan sampling) during photophase, which lasted 18 hours per day (Bokkers and Koene, 2003).
RE36		*Dim light*	all	< 5 lux (Davis et al., 1999; Olanrewaju et al., 2006; Kristensen et al., 2007)	< 5 lux (Olanrewaju et al., 2006)	< 5 lux (Olanrewaju et al., 2006)	Although resting is also done in brighter light, broilers prefer dim light when resting on perches (Kristensen et al., 2007).
RE37		*Light frequency above flicker sensitivity treshold*	all	> 54 Hz (Jarvis et al., 2002)	> 54 Hz (Jarvis et al., 2002)	> 54 Hz (Jarvis et al., 2002)	Peak sensitivity for photopic flicker occurs around 15 Hz in adult laying hens, but is affected by light intensity. With light intensity of 8 lux the flicker sensitivity threshold for adult laying hens was measured at 54 Hz (Jarvis et al., 2002). It is assumed that flicker sensitivity in broilers is similar to that of laying hens.
RE38	**Good physical health**	*Maximal allowed score for foot pad dermatitis*	all	A	A	A	Foot pad dermatitis score indicates the severity of contact dermatitis on the skin of the foot. Main cause of foot pad dermatitis is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of foot pad dermatitis at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. Resting during scotophase was defined as resting on perches. The lowest score indicated was B, the highest score was C, and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: A = no evidence of foot pad dermatitis; B = minimal evidence of foot pad dermatitis; C = evidence of foot pad dermatitis (Welfare Quality, 2009 p.35).
RE39		*Maximal allowed score for hock burn*	all	A	A	A	Hock burn score indicates the severity of contact dermatitis on the skin of the caudal part of the hock joint. Main cause of hock burn is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of hock burn at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. Resting during scotophase was defined as resting on perches. The lowest score indicated was B, the highest score was > C (i.e. behaviour is not likely to be affected by any degree of hock burn), and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: A = no evidence of hock burn; B = minimal evidence of hock burn; C = evidence of hock burn (Welfare Quality, 2009 p.35).
RE40		*Maximal allowed score for gait*	all	0	0	0	Gait score indicates how severely leg weaknesses affect walking ability. Five experts were asked to determine the gait score at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. Resting during scotophase was defined as resting on perches. The lowest score indicated was 1, the highest score was 2, and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). In short, scores are classified as: 0 = no abnormalities in gait; 1 = slight abnormality in gait, without clear causation; 2 = clear abnormality in gait, but chicken is able to move when necessary; 3 = clear abnormality in gait, ability to move is severely reduced; 4 = severe abnormality in gait, chicken can move only with great difficulty and will only walk when very motivated or when driven; 5 = extremely severe abnormality in gait, chicken is incapable of sustained walking (Welfare Quality, 2009 p.34). For extensive descriptions of the different scoring categories defined in the gait scoring method, see Kestin et al. (1992).
RE41		*Maximal allowed score for breast blister*	all	0	0	0	Breast blisters are caused by contact dermatitis of the skin overlying the keel (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of breast blistes at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. Resting during scotophase was defined as resting on perches. The lowest score indicated was 1, the highest score was > 1 (i.e. behaviour is not likely to be affected by breast blisters) and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: 0 = no breast blister; 1 = breast blister present (Welfare Quality, 2009 p.41).

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
Sun bath (SU)							
SU1		*Light spectrum resembling daylight (including UV)*	all				Possible functions of sun bathing are synthesis of vitamins (Lewis and Gous, 2009), uptake of warmth and removal of parasites. Additionally, laying hens appear to use the sun as a means for orientation (Zimmerman et al., 2009), although it is unknown if the same applies to broilers.
SU2		*Space*	all	see space requirements for resting/sleeping	see space requirements for resting/sleeping	see space requirements for resting/sleeping	It is assumed that sun bathing is done in a position similar to resting.

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
Preen (PR)							
PR1		*Time spent preening (% of photophase)*	A	3% (Bokkers and Koene, 2003)		2% (Bokkers and Koene, 2003)	
PR2			B	2 - 4.5% (Bokkers and Koene, 2003; Shields et al., 2005)		7% (Bokkers and Koene, 2003)	In the study of Shields and colleagues (2005) two types of bedding were used, namely sand and wood shavings. Time budgets mentioned here were taken from the results found for broilers housed on sand as this seemed to be favored above wood shavings, indicated by higher levels of activity in pens with sand bedding.
PR3			C	2.5 - 6.9% (Bokkers and Koene, 2003; Shields et al., 2005)		6.6% (Bokkers and Koene, 2003)	In the study of Shields and colleagues (2005) two types of bedding were used, namely sand and wood shavings. Time budgets mentioned here were taken from the results found for broilers housed on sand as this seemed to be favored above wood shavings, indicated by higher levels of activity in pens with sand bedding.
PR4			D	Not applicable		6% (Bokkers and Koene, 2003)	
PR5		*Area*	A				No data on cross sectional area occupied per chicken was found for this age.
PR6			B	Maximal stocking density 40-50 animals/m^2 (ASG, 2010)			Stocking density of 50 animals/m^2 led to decrease in preening, when compared to a lower density (ASG, 2010). This likely indicates restrictions in ability to move as result of decrease in amount of space available per animal. No data on cross sectional area occupied per chicken was found for this age.
PR7			C	Recommended area: 1235.8 cm^2/animal or 8 animals/m^2 or 20.2 kg/m^2; but see explanation			Range found for recommended maximal stocking density at end of growing period: 635.6 - 1235.8 cm^2/animal or 8 - 15 animals/m^2 or 20.2 - 37.5 kg/m^2 when assuming that average weight at slaughter is 2.5 kg (Dawkins and Hardie, 1989; Bokkers et al., in press). From these ranges the value providing the most space per animal was chosen as area recommendation to ensure that each broiler is always provided with sufficient space. Bokkers et al. (in press) differentiated between preening in standing position and preening in sitting position, with recommendations ranging from 668.1 cm^2/animal to 635.6 cm^2/animal respectively (Bokkers et al., in press). Cross sectional area was calculated as the mean of values found for male (703.6 cm^2/animal in standing position; 657.4 cm^2/animal in sitting position) and female (632.5 cm^2/animal in standing position; 613.8 cm^2/animal in sitting position) broilers at six weeks of age (Bokkers et al., in press) as it is assumed that broilers are not sexed prior to rearing, leading on average to a 1:1 ratio of male and female broilers. In addition data on laying hens was used: cross sectional area was adapted from area given for adult laying hens (1150.6 cm^2/animal) with mean weight of 2.02 kg (Dawkins and Hardie, 1989); value was adapted for mean weight of 2.5 kg by using the formula: width of individual = 0.064*W^0.33 (Petherick, 2007; Petherick and Philips, 2009) to calculate body widths corresponding with weights of 2.02 kg and 2.5 kg. With the calculated body width for animals weighing 2.5 kg the cross sectional area for animals weighing 2.02 kg was adjusted. Laying hens differ in body morphology compared to broilers but it was assumed that this difference is caused by differences in body width and not body length. This adaptation was done to give an indication for the expected value for cross sectional area in broilers, but this value needs scientific validation.
PR8			D	Not applicable			
PR9		*Sufficient light*	all	200 lux (Davis et al., 1999; Alvino et al., 2009a)			Value given here indicates that broilers prefer to preen in a relatively bright environment. However, precise preference is not known due to experimental constraints (e.g. using three different light intensities per trail, as in Alvino et al., 2009a). Peaks in preening occur at start and end of photophase (Alvino et al., 2009a). Light intensity affects synchronisation of preening, with higher intensity (200 lux versus 50 or 5 lux) inducing higher levels of synchronisation (Alvino et al., 2009b).
PR10		*Light spectrum resembling daylight*	C	400 < λ < 750 nm (Kristensen et al., 2007)			
PR11		*Light frequency above flicker sensitivity treshold*	all	> 72 Hz (Jarvis et al., 2002)	> 72 Hz (Jarvis et al., 2002)	> 72 Hz (Jarvis et al., 2002)	Peak sensitivity for photopic flicker occurs around 15 Hz in adult laying hens, but is affected by light intensity. With light intensity of 40 lux the flicker sensitivity threshold for adult laying hens was measured at 71.5 Hz, and this threshold reduced at lower light intensities (Jarvis et al., 2002). It is assumed that flicker sensitivity in broilers is similar to that of laying hens.

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
PR12	**Good physical health**	*Maximal allowed score for foot pad dermatitis*	all	B	B	B	Foot pad dermatitis score indicates the severity of contact dermatitis on the skin of the foot. Main cause of foot pad dermatitis is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of foot pad dermatitis at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was C, the highest score was > C (i.e. behaviour is not likely to be affected by any degree of foot pad dermatitis), and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: A = no evidence of foot pad dermatitis; B = minimal evidence of foot pad dermatitis; C = evidence of foot pad dermatitis (Welfare Quality, 2009 p.35).
PR13		*Maximal allowed score for hock burn*	all	B	B	B	Hock burn score indicates the severity of contact dermatitis on the skin of the caudal part of the hock joint. Main cause of hock burn is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of hock burn at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was C, the highest score was > C (i.e. behaviour is not likely to be affected by any degree of hock burn), and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: A = no evidence of hock burn; B = minimal evidence of hock burn; C = evidence of hock burn (Welfare Quality, 2009 p.35).
PR14		*Maximal allowed score for gait*	all	1	1	1	Gait score indicates how severely leg weaknesses affect walking ability. Five experts were asked to determine the gait score at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was 2, the highest score was 4, and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). In short, scores are classified as: 0 = no abnormalities in gait; 1 = slight abnormality in gait, without clear causation; 2 = clear abnormality in gait, but chicken is able to move when necessary; 3 = clear abnormality in gait, ability to move is severely reduced; 4 = severe abnormality in gait, chicken can move only with great difficulty and will only walk when very motivated or when driven; 5 = extremely severe abnormality in gait, chicken is incapable of sustained walking (Welfare Quality, 2009 p.34). For extensive descriptions of the different scoring categories defined in the gait scoring method, see Kestin et al. (1992).
PR15		*Maximal allowed score for breast blister*	all	0	0	0	Breast blisters are caused by contact dermatitis of the skin overlying the keel (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of breast blistes at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was 1, the highest score was > 1 (i.e. behaviour is not likely to be affected by breast blisters) and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: 0 = no breast blister; 1 = breast blister present (Welfare Quality, 2009 p.41).
Dust Bath (DU)							
DU1	**Time**	*Time spent dustbathing (% of photophase)*	A	1.5% (Bokkers and Koene, 2003)		1% (Bokkers and Koene, 2003)	Dustbathing is mainly done during photophase in a diurnal rhythm (i.e. once in two days), with dustbathing bouts reaching a peak after 6 to 7 hours of light (Vestergaard, 1982).
DU2			B	1 - 3% (Bokkers and Koene, 2003; Shields et al., 2005)		2% (Bokkers and Koene, 2003)	In the study of Shields and colleagues (2005) two types of bedding were used, namely sand and wood shavings. Time budgets mentioned here were taken from the results found for broilers housed on sand as this seemed to be favored above wood shavings, indicated by higher levels of activity in pens with sand bedding.
DU3			C	1 - 1.9% (Bokkers and Koene, 2003; Shields et al., 2004)		2.4% (Bokkers and Koene, 2003)	In the study of Shields and colleagues (2005) two types of bedding were used, namely sand and wood shavings. Time budgets mentioned here were taken from the results found for broilers housed on sand as this seemed to be favored above wood shavings, indicated by higher levels of activity in pens with sand bedding.
DU4			D	Not applicable		3.6% (Bokkers and Koene, 2003)	
DU5	**Space**	*Area*	A				Space available per animal should be sufficient to perform the full repertoire of dustbathing behaviour, i.e. squatting in dustbathing material, bill raking, scratching, vertical wing-shaking, head rubbing, lying on the side, feather raising, body/wing shaking (Vestergaard, 1982). No data on cross sectional area occupied per chicken was found for this age.

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
DU6			B	Maximal stocking density 30-40 animals/m^2 (ASG, 2010)			Stocking density of 40 animals/m^2 led to decrease in dustbathing, when compared to a lower density (ASG, 2010). This likely indicates restrictions in ability to move as result of decrease in amount of space available per animal. No data on cross sectional area occupied per chicken was found for this age.
DU7			C	Recommended area: 938 cm^2/animal or 10 animals/m^2 or 26.6 kg/m^2; but see explanation			Range found for recommended maximal stocking density at end of growing period: 728.2 - 938 cm^2/animal or 10 - 13 animals/m^2 or 26.6 - 32.5 kg/m^2 when assuming that average weight at slaughter is 2.5 kg (Dawkins and Hardie, 1989; Bokkers et al., in press). From these ranges the value providing the most space per animal was chosen as area recommendation to ensure that each broiler is always provided with sufficient space. Cross sectional area was calculated as the mean of values found for male (762.4 cm^2/animal) and female (694 cm^2/animal) broilers at six weeks of age (Bokkers et al., in press) as it is assumed that broilers are not sexed prior to rearing, leading on average to a 1:1 ratio of male and female broilers. In addition data on laying hens was used: cross sectional area was adapted from area given for adult laying hens (873.3 cm^2/animal) with mean weight of 2.02 kg (Dawkins and Hardie, 1989) for the behaviour defined as feather ruffling; value was adapted for mean weight of 2.5 kg by using the formula: width of individual = 0.064*W^0.33 (Petherick, 2007; Petherick and Philips, 2009) to calculate body widths corresponding with weights of 2.02 kg and 2.5 kg. With the calculated body width for animals weighing 2.5 kg the cross sectional area for animals weighing 2.02 kg was adjusted. Laying hens differ in body morphology compared to broilers but it was assumed that this difference is caused by differences in body width and not body length. This adaptation was done to give an indication for the expected value for cross sectional area in broilers, but this value needs scientific validation.
DU8			D	Not applicable			
DU9	**Substrate**	*Amount*	all				Absence of suitable substrate might induce feather pecking as compensatory behaviour for ground pecking or dust bathing (Savory, 1995). No indication for amount of substrate that should be provided for broilers was found.
DU10		*Dry material*	all	Completely dry and loose (Welfare Quality, 2009)	Completely dry and loose (Welfare Quality, 2009)	Completely dry and loose (Welfare Quality, 2009)	
DU11		*Loose material*	all	Easy to move with feet, wing or beak (Welfare Quality, 2009)	Easy to move with feet, wing or beak (Welfare Quality, 2009)	Easy to move with feet, wing or beak (Welfare Quality, 2009)	
DU12		*Small particles*	all	Particles that are fine enough to penetrate the feathers and reach the downy part of the plumage (Vestergaard, 1982; Petherick and Duncan, 1989; Sanotra et al., 1995; Shields et al., 2004, 2005)	Particles that are fine enough to penetrate the feathers and reach the downy part of the plumage (Vestergaard, 1982; Petherick and Duncan, 1989; Sanotra et al., 1995; Shields et al., 2004, 2005)	Particles that are fine enough to penetrate the feathers and reach the downy part of the plumage (Vestergaard, 1982; Petherick and Duncan, 1989; Sanotra et al., 1995; Shields et al., 2004, 2005)	Function of dust bathing is to remove ectoparasites and excess fatty oils from feathers (Vestergaard, 1982; Petherick and Duncan, 1989; Sanotra et al., 1995). Ideal particle size is not known, but it has been observed that broilers, laying hens and domestic fowls prefer sand or peat over straw, wood-shavings, feathers, rice hulls or recycled paper bedding for dustbathing (Petherick and Duncan, 1989; Sanotra et al., 1995; Shields et al., 2004, 2005; De Jong et al., 2007).
DU13	**Lighting**	*Sufficient light*	all	200 lux (Davis et al., 1999; Alvino et al., 2009)			Value given here indicates that broilers prefer to dust bathe in a relatively bright environment. However, precise preference is not known due to experimental constraints (e.g. using only three different light intensities per trail, as in Alvino et al., 2009).
DU14		*Light spectrum resembling daylight*	C	$400 < \lambda < 750$ nm (Kristensen et al., 2007)			
DU15		*Light frequency above flicker sensitivity treshold*	all	> 72 Hz (Jarvis et al., 2002)	> 72 Hz (Jarvis et al., 2002)	> 72 Hz (Jarvis et al., 2002)	Peak sensitivity for photopic flicker occurs around 15 Hz in adult laying hens, but is affected by light intensity. With light intensity of 40 lux the flicker sensitivity threshold for adult laying hens was measured at 71.5 Hz, and this threshold reduced at lower light intensities (Jarvis et al., 2002). It is assumed that flicker sensitivity in broilers is similar to that of laying hens.
DU16	**Good physical health**	*Maximal allowed score for foot pad dermatitis*	all	A	A	A	Foot pad dermatitis score indicates the severity of contact dermatitis on the skin of the foot. Main cause of foot pad dermatitis is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of foot pad dermatitis at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was B, the highest score was > C (i.e. behaviour is not likely to be affected by any degree of foot pad dermatitis), and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: A = no evidence of foot pad dermatitis; B = minimal evidence of foot pad dermatitis; C = evidence of foot pad dermatitis (Welfare Quality, 2009 p.35).

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
DU17		*Maximal allowed score for hock burn*	all	B	B	B	Hock burn score indicates the severity of contact dermatitis on the skin of the caudal part of the hock joint. Main cause of hock burn is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of hock burn at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was C, the highest score was > C (i.e. behaviour is not likely to be affected by any degree of hock burn), and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: A = no evidence of hock burn; B = minimal evidence of hock burn; C = evidence of hock burn (Welfare Quality, 2009 p.35).
DU18		*Maximal allowed score for gait*	all	0	0	0	Gait score indicates how severely leg weaknesses affect walking ability. Five experts were asked to determine the gait score at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was 1, the highest score was 3, and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). In short, scores are classified as: 0 = no abnormalities in gait; 1 = slight abnormality in gait, without clear causation; 2 = clear abnormality in gait, but chicken is able to move when necessary; 3 = clear abnormality in gait, ability to move is severely reduced; 4 = severe abnormality in gait, chicken can move only with great difficulty and will only walk when very motivated or when driven; 5 = extremely severe abnormality in gait, chicken is incapable of sustained walking (Welfare Quality, 2009 p.34). For extensive descriptions of the different scoring categories defined in the gait scoring method, see Kestin et al. (1992).
DU19		*Maximal allowed score for breast blister*	all	0	0	0	Breast blisters are caused by contact dermatitis of the skin overlying the keel (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of breast blistes at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was 1, the highest score was > 1 (i.e. behaviour is not likely to be affected by breast blisters) and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: 0 = no breast blister; 1 = breast blister present (Welfare Quality, 2009 p.41).

Wing and leg stretch (WI)

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
WI1	**Space**	*Area*	A				No data on cross sectional area occupied per chicken was found for this age.
WI2			B	Maximal stocking density 40-50 animals/m^2 (ASG, 2010)			Stocking density of 50 animals/m^2 led to decrease in comfort behaviour, when compared to a lower density (ASG, 2010). This likely indicates restrictions in ability to move as result of decrease in amount of space available per animal. No data on cross sectional area occupied per chicken was found for this age.
WI3			C	Recommended area: 2015.3 cm^2/animal or 5 animals/m^2 or 12.4 kg/m^2; but see explanation			Range found for recommended maximal stocking density at end of growing period: 637.8 - 2015.3 cm^2/animal or 5 - 15 animals/m^2 or 12.4 - 37.5 kg/m^2 when assuming that average weight at slaughter is 2.5 kg (Dawkins and Hardie, 1989; Bokkers et al., in press). From these ranges the value providing the most space per animal was chosen as area recommendation to ensure that each broiler is always provided with sufficient space. Bokkers et al. (in press) differentiated between stretching in standing position and stretching in sitting position, with recommendations ranging from 766.2 cm^2/animal to 637.8 cm^2/animal respectively (Bokkers et al., in press). Cross sectional area was calculated as the mean of values found for male (814 cm^2/animal in standing position; 671.8 cm^2/animal in sitting position) and female (718.4 cm^2/animal in standing position; 603.8 cm^2/animal in sitting position) broilers at six weeks of age (Bokkers et al., in press) as it is assumed that broilers are not sexed prior to rearing, leading on average to a 1:1 ratio of male and female broilers. In addition data on laying hens was used: cross sectional area was adapted from area given for adult laying hens (892.9 cm2/animal for wing stretching and 1876.3 cm2/animal for wing flapping) with mean weight of 2.02 kg (Dawkins and Hardie, 1989); value was adapted for mean weight of 2.5 kg by using the formula: width of individual = 0.064*W^0.33 (Petherick, 2007; Petherick and Philips, 2009) to calculate body widths corresponding with weights of 2.02 kg and 2.5 kg. With the calculated body width for animals weighing 2.5 kg the cross sectional area for animals weighing 2.02 kg was adjusted. Laying hens differ in body morphology compared to broilers but it was assumed that this difference is caused by differences in body width and not body length. This adaptation was done to give an indication for the expected value for cross sectional area in broilers, but this value needs scientific validation.
WI4			D	Not applicable			No data on cross sectional area occupied per chicken was found for this age.

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
Social Interaction (SO)							
SO1		*Living in a group*	all				Broilers will usually not form a hierarchy, because the group size in which they are commonly kept is too large and the animals are too young. However the absence of hierarchy and the large group size (which prevents recognition) does not seem to have detrimental effects on the broilers as they do not form subgroups but continue to fully use their available space. Playing is often a social event (i.e. performed by more than one broiler simultaneously) and playing is important for strenghtening of skeleton and muscles, and for obtaining/practicing social skills. Playing in wild fowl is also related to behaviours important for survival in natural circumstances. Data on ideal group size for broilers was not found.
SO2		*Group composition*	all				Puberty in males starts around 56 days of age with play and fight behaviour, and around 70 days the males start crowing. Data on ideal group composition for broilers, or consequences of non-ideal group composition were not found.
SO3	**Lighting**	*Sufficient light*	all	200 lux (Davis et al., 1999; Alvino et al., 2009)			Broilers should be able to clearly see each other.
SO4		*Light spectrum resembling daylight (including UVa)*	all	Visible light: 400 < λ < 750 nm (Kristensen et al., 2007) UVa light: 320 < λ < 400 nm (Prescott and Wathes, 1999)			Broilers should be able to clearly see each other, in order to recognize individuals or assess one's intentions when in confrontation. Feathers of domestic fowls seem to reflect UVa light (320 < λ < 400 nm), which might function to enhance recognition by others (Prescott and Wathes, 1999). However these UVa reflections appear to be quite subtle, and it can be questioned whether UVa light is truly required or that broilers can also adequately recognize each other in visible light (400 < λ < 750 nm) of sufficient intensity.
SO5		*Light frequency above flicker sensitivity treshold*	all	> 72 Hz (Jarvis et al., 2002)	> 72 Hz (Jarvis et al., 2002)	> 72 Hz (Jarvis et al., 2002)	Peak sensitivity for photopic flicker occurs around 15 Hz in adult laying hens, but is affected by light intensity. With light intensity of 40 lux the flicker sensitivity threshold for adult laying hens was measured at 71.5 Hz, and this threshold reduced at lower light intensities (Jarvis et al., 2002). It is assumed that flicker sensitivity in broilers is similar to that of laying hens.
SO6	**Space**	*Area*	all	Sufficient space available to run (ASG, 2010)			Especially young broiler chicks have been observed to run around in their pen in bouts (ASG, 2010) without no apparent reason. Running of one (group of) chick can elicit running in other chicks, but it is not regarded as a truly social behaviour. Reasons or motivations for running are unknown, but it could be a form of play behaviour or a need to exercise muscles.
SO7		*Ability to group with conspecifics*	all	Access to center of perimeter (Cornetto and Estevez, 2001; Buijs et al., 2010)	Access to center of perimeter (Cornetto and Estevez, 2001; Buijs et al., 2010)	Access to center of perimeter (Cornetto and Estevez, 2001; Buijs et al., 2010)	Broilers can require protection from their conspecifics during activities when chickens are vulnerable, e.g. resting, preening (Cornetto and Estevez, 2001), which has developed in the course of evolution as protection against predators but is less relevant for modern broilers. The perimeter is formed either by the group of broilers in which a broiler is present, or the physical barriers of the environment in which this group is placed.
SO8		*Ability to avoid conspecifics*	all	Access to borders of perimeter when stocking density > 12 animals/m^2 or >33 kg/m^2 (Cornetto and Estevez, 2001; Buijs et al., 2010)	Access to borders of perimeter when stocking density > 12 animals/m^2 or >33 kg/m^2 (Cornetto and Estevez, 2001; Buijs et al., 2010)	Access to borders of perimeter when stocking density > 12 animals/m^2 or >33 kg/m^2 (Cornetto and Estevez, 2001; Buijs et al., 2010)	Broilers can require an increase in their personal space, i.e. "the area around an individual which it tries to keep free of conspecifics" (Keeling, 1995), if stocking density gets too high. This can be accomplished for instance by moving to the borders of the perimeter and so avoid disturbance by other chickens present in their environment (Buijs et al., 2010).
SO9	**Good physical health**	*Maximal allowed score for foot pad dermatitis*	all	A	A	A	Foot pad dermatitis score indicates the severity of contact dermatitis on the skin of the foot. Main cause of foot pad dermatitis is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of foot pad dermatitis at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was B, the highest score was > C (i.e. behaviour is not likely to be affected by any degree of foot pad dermatitis), and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: A = no evidence of foot pad dermatitis; B = minimal evidence of foot pad dermatitis; C = evidence of foot pad dermatitis (Welfare Quality, 2009 p.35).
SO10		*Maximal allowed score for hock burn*	all	A	A	A	Hock burn score indicates the severity of contact dermatitis on the skin of the caudal part of the hock joint. Main cause of hock burn is contact with soiled litter (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of hock burn at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was B, the highest score was > C (i.e. behaviour is not likely to be affected by any degree of hock burn), and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: A = no evidence of hock burn; B = minimal evidence of hock burn; C = evidence of hock burn (Welfare Quality, 2009 p.35).

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
SO11		*Maximal allowed score for gait*	all	0	0	0	Gait score indicates how severely leg weaknesses affect walking ability. Five experts were asked to determine the gait score at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was 1, the highest score was 2, and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). In short, scores are classified as: 0 = no abnormalities in gait; 1 = slight abnormality in gait, without clear causation; 2 = clear abnormality in gait, but chicken is able to move when necessary; 3 = clear abnormality in gait, ability to move is severely reduced; 4 = severe abnormality in gait, chicken can move only with great difficulty and will only walk when very motivated or when driven; 5 = extremely severe abnormality in gait, chicken is incapable of sustained walking (Welfare Quality, 2009 p.34). For extensive descriptions of the different scoring categories defined in the gait scoring method, see Kestin et al. (1992).
SO12		*Maximal allowed score for breast blister*	all	0	0	0	Breast blisters are caused by contact dermatitis of the skin overlying the keel (Welfare Quality, 2009). Five experts were asked to determine the score for occurrence of breast blistes at which behaviour is likely to be altered, as it is assumed that alterations in behaviour can be used as an indication for decreased welfare. The lowest score indicated was 1, the highest score was > 1 (i.e. behaviour is not likely to be affected by breast blisters) and to guarantee good welfare the lowest score was chosen as indicator of decreased welfare. Maximal allowed score is thus one category below the first indication of decreased welfare (i.e. lowest score minus 1). Classification of score: 0 = no breast blister; 1 = breast blister present (Welfare Quality, 2009 p.41).
SO13	**Synchronisation / social facilitation**	*Space*	all				Social facilitation occurs when "observation of other birds expressing a particular behaviour elicits expression in the observers" (Anonymous, 2001 p.38). However it is not known if, and for which behaviours, social facilitation occurs in broilers.
SO14		*Light intensity*	all	200 lux (Davis et al., 1999; Alvino et al., 2009a)			Synchronisation of foraging behaviour increases with brighter lighting (Alvino et al., 2009b). For social facilitation to occurs, chickens need to be able to see each other clearly.

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
Aerial Environment (AE)							
AE1		*Maximal allowed concentration of dust particles in air*	all	1.7 mg/m^3 respirable dust with particle size PM2.5; and 3.4 mg/m^3 inhalable dust with particle size PM100 (Calvet et al., 2009)	1.7 mg/m^3 respirable dust with particle size PM2.5; and 3.4 mg/m^3 inhalable dust with particle size PM100 (Calvet et al., 2009)	1.7 mg/m^3 respirable dust with particle size PM2.5; and 3.4 mg/m^3 inhalable dust with particle size PM100 (Calvet et al., 2009)	Inhalable dust consists of particles with diameter of 100 microns (PM100) or less which will enter the nose and mouth during normal breathing. Respirable dust consists of particles with diameter of 2.5 microns (PM2.5) which will penetrate into the gas exchange region of the lungs (Takei et al., 1998; Calvet et al., 2009). No recommended maximal values were found for concentrations of thoracic dust, consisting of particles with diameter of 10 microns (PM10) or less which will pass through the nose and throat and will reach the lungs.
AE2		*Optimal oxygen (O_2) concentration*	all	20.5% (ASG, 2004)	20.5% (ASG, 2004)	20.5% (ASG, 2004)	
AE3		*Maximal allowed concentration of NH_3*	all	< 10 ppm at bird height (Jones et al., 2005)	< 10 ppm at bird height (Jones et al., 2005)	< 10 ppm at bird height (Jones et al., 2005)	
AE4		*Maximal allowed concentration of CO*	all	< 100 ppm at bird head height (ASG, 2004)	< 100 ppm at bird head height (ASG, 2004)	< 100 ppm at bird head height (ASG, 2004)	
AE5		*Maximal allowed concentration of CO_2*	all	< 2000 ppm at bird head height (ASG, 2004)	< 2000 ppm at bird head height (ASG, 2004)	< 2000 ppm at bird head height (ASG, 2004)	
AE6		*Maximal allowed concentration of H_2S*	all	< 20 ppm at bird head height (ASG, 2004)	< 20 ppm at bird head height (ASG, 2004)	< 20 ppm at bird head height (ASG, 2004)	
AE7		*Maximal allowed concentration of SO_2*	all	< 5 ppm at bird head height (ASG, 2004)	< 5 ppm at bird head height (ASG, 2004)	< 5 ppm at bird head height (ASG, 2004)	
Thermal Environment (TH)							
TH1		*Environmental temperature within thermoneutral zone*	A	32 - 35 °C at day 0 posthatch, reducing to 30 - 33.5 °C at day 4 of age (ASG, 2004; Segura et al., 2006; Aviagen, 2007a,b; Ross, 2007; De Faria Filho et al., 2007)	32 °C at day 0 posthatch, reducing to 30 °C at day 4 of age (ASG, 2004; Cobb-Vantress, 2010)		Young chickens have a conjoint preference for a warm and brightly lit environment (Alsam and Wathes, 1991a), and are sensitive to cold-induced stress (Mujahid and Furuse, 2009) while later in life chickens become more sensitive to heat-induced stress (Yalcin et al., 2001). Medium and slow growing broilers are less sensitive to heat stress compared to fast growing broilers, as fast growing broilers produce more heat (Yalcin et al., 2001; Quentin et al., 2003). Chickens are able to maintain their preferred body temperature by behavioural thermoregulation (Alsam and Wathes, 1991b). Range was partly determined by using Table 2.9 (p.57) of ASG (2004) combined with productsheets of representative commercial strains (Aviagen 2007ab; Ross 2007; Cobb-Vantress 2010).
TH2			B	30 - 33.5 °C at day 5 of age, reducing to 27 - 29 °C at day 14 of age (ASG, 2004; Segura et al., 2006; Aviagen, 2007a,b; Ross, 2007; De Faria Filho et al., 2007)	30 °C at day 5 of age, reducing to 27 °C at day 14 of age (ASG, 2004; Cobb-Vantress, 2010)		
TH3			C	27 - 29 °C at day 15 of age, reducing to 18 - 20 °C from day 24 of age onwards (ASG, 2004; Segura et al., 2006; Aviagen, 2007a,b; Ross, 2007; De Faria Filho et al., 2007)	27 °C at day 15 of age, reducing to 18 - 20 °C from day 24 of age onwards (ASG, 2004; Cobb-Vantress, 2010)	32 °C at day 15 of age, reducing to 24 °C from day 24 of age onwards (Ali et al., 2010)	
TH4			D	Not applicable	18 - 20 °C (ASG, 2004; Cobb-Vantress, 2010)	24 °C (Ali et al., 2010)	
TH5		*Humidity within optimal range*	all	Range: 44 - 68 % (De Faria Filho et al., 2007)		Range: 52 - 58 % (Ali et al., 2010)	Impact of relative humidity is dependent on ambient temperature (Lin et al., 2005ab). If relative humidity and/or ambient temperature repeatedly, or for prolonged periods of time, reach levels above maximum recommended values, then ability to loose excess heat, mortality and the prevalence and severity of leg weakness and foot pad dermatitis are negatively affected (Dawkins et al., 2004; Jones et al., 2005).
TH6	**No draft**	*Restricted air velocity*	all	≤ 0.2 m/s (ASG, 2004)	≤ 0.2 m/s (ASG, 2004)	≤ 0.2 m/s (ASG, 2004)	
Microbial Environment (MI)							
MI1	**Absence of clinical signs of infections**	*No clinical signs of infection with Escherichia coli*	all				General recommendations are to restrict exposure to bacteria, restrict stress (induced by e.g. draft, catching, transportation) and keep immune resistance high (ASG, 2004).
MI2		*No clinical signs of infection with New Castle Disease*	all				General recommendations are to restrict exposure to virus, restrict stress (induced by e.g. draft, catching, transportation) and keep immune resistance high (ASG, 2004).

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MI3		*No clinical signs of infection with Infectious bronchitis*	all				General recommendations are to restrict exposure to virus, restrict stress (induced by e.g. draft, catching, transportation) and keep immune resistance high (ASG, 2004).
MI4		*No clinical signs of infection with Coccidiosis*	all				General recommendations are to restrict exposure to parasite, restrict stress (induced by e.g. draft, catching, transportation) and keep immune resistance high (ASG, 2004).
MI5		*No clinical signs of infection with Salmonella gallinarum*	all				General recommendations are to restrict exposure to bacteria, restrict stress (induced by e.g. draft, catching, transportation) and keep immune resistance high (ASG, 2004).
MI6		*No clinical signs of infection with Salmonella java*	all				General recommendations are to restrict exposure to bacteria, restrict stress (induced by e.g. draft, catching, transportation) and keep immune resistance high (ASG, 2004).
MI7		*No clinical signs of infection with Infectious coryza*	all				General recommendations are to restrict exposure to bacteria, restrict stress (induced by e.g. draft, catching, transportation) and keep immune resistance high (ASG, 2004).
MI8		*No clinical signs of infection with Ornithobacterium rhinotracheale*	all				General recommendations are to restrict exposure to bacteria, restrict stress (induced by e.g. draft, catching, transportation) and keep immune resistance high (ASG, 2004).
MI9		*No clinical signs of infection with Campylobacter*	all				General recommendations are to restrict exposure to bacteria, restrict stress (induced by e.g. draft, catching, transportation) and keep immune resistance high (ASG, 2004).
MI10	**No severe acute or chronic stress**	*Ability to cope with changes in the environment*	all				Inability to cope with environmental changes causes stress.
MI11		*Restriction of background noise*	all				Chickens can be startled when sudden events such as loud noises occur, which could lead to hysteria, crowding and possibly even death by oppression. Maximal acceptable level of background noise is not known.
MI12		*Restriction of stress experienced during catching, transportation and slaughter*	CD				Broilers should be handled with care during catching procedures and transportation, and should be slaughtered humanely (Welfare Quality, 2009).
MI13	**Intact integrity**	*All body parts intact*	A				This also implies no beak or toe trimming.
Spatial Environment (SP)							
SP1	**Cognitive stimulation**	*Enough stimulating elements in environment*	all				No data on the relevance of cognitive stimulation for broilers was found, but from a biological perspective it can be argued that absence of cognitive stimulation could compromise welfare.

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
Feed Intake (FE)							
FE1	**Structure**		AB	Hard feed (Bouvarel et al., 2009)			Broilers prefer hard feed over soft feed but hardness is not most important factor in choosing feed, although it does influence speed of food intake (Bouvarel et al., 2009).
FE2			CD	Hard feed (Bouvarel et al., 2009)			
FE3	**Size**		AB (1-7)	Particle size: GMD = 900 - 1100 µm (Nir and Ptichi, 2001)			Optimal particle size range represents particle size providing the most efficient digestion of the feed (Amerah et al., 2007). Preferred particle size increases with age, possible correlated with beak dimensions (Portella et al., 1988). Ideal particle size range is unknown, but crumbs or small pellets (diameter <3.2 mm) are preferred over mash (Engberg et al., 2002; Cerrate et al., 2009; Mirghelenj and Golian, 2009), but not if pellet size is too large (Delezie, 2009). Slow growing broilers show no preference for particle size (Quentin et al., 2004). If feed is larger it should be possible for the chickens to take it apart themselves. Abbreviations: GMD = geometric mean diameter.
FE4			BC (7-21)	Particle size: GMD = 1100 - 1300 µm (Nir and Ptichi, 2001).			
FE5			CD (21-end)	Particle size: GMD = 1300 - 1500 µm (Nir and Ptichi, 2001).			
FE6	**Colour**		A	Light/pale colours (Bouvarel et al., 2009)			Paleness and fat content of food might be confounding factors (Bouvarel et al., 2008, 2009).
FE7			BC				No colour preference was found for this age.
FE8			D	Light/pale colours (Chagneau et al., 2006)			Paleness and fat content of food might be confounding factors (Bouvarel et al., 2008, 2009).
FE9	**Availability of food**	*Reward for foraging behaviour*	all	Food reward present in foraging substrate	Food reward present in foraging substrate	Food reward present in foraging substrate	Chickens are grazers, i.e. they tend to forage constantly during the day, and to satisfy this need foraging behaviour should be rewarded (with food) regularly. However the danger is that especially fast growing broilers will overeat, which can cause physical problems.
FE10	**Energy provision**	*Metabolisable energy*	all	Fast growing broilers will adjust feed intake to meet their energy requirements when fed a low nutrient diet (Fanatico et al., 2008)	Medium growing broilers will adjust feed intake to meet their energy requirements when fed a low nutrient diet (Fanatico et al., 2008)	Slow growing broilers are less inclined than fast or medium growing broilers to increase feed intake in order to meet energy requirements when fed a low nutrient diet (Fanatico et al., 2008)	Metabolisable energy, or effective energy, is the fraction of energy intake that can be used for maintenance, growth and production, determined as the difference between the gross energy of the feed, and the gross energy of the excreta derived from the same feed (Lopez and Leeson, 2008). Total effective energy requirement of growing animals can be calculated with: EEREQg (in MJ/day) = Me x P / Pm0.27 + Z1 x P x loge (Pm / P) + Z2 x B x L x loge (Lm / L) (Emmans and Kyriazakis, 2001); with Me = energy constant with estimated value of 1.63 MJ/unit (Emmans, 1994); P = requirement for protein retention; Pm = requirement to reach mature level of protein retention; Z1 = energy constant with estimated value of 50 MJ/kg (Emmans, 1994); Z2 = energy constant with estimated value of 56 MJ/kg (Emmans, 1994); L = requirement for lipid retention; Lm = requirement to reach mature level of lipid retention.
FE11		*Balanced ratio of carbohydrates, proteins and fats*	A	Preference for high protein/low energy diet after hatch, shifting towards low protein/high energy diet at end of life stage A (Siegel et al., 1997)	Preference for high protein/low energy diet immediately after hatch, but quick shift (within few days) to low protein/high energy diet (Siegel et al., 1997)		Demand for (ratios of) nutrients fluctuates over time: first more proteins for growth, later more energy for maintenance. Crude protein content affects efficiency of utilisation of amino acids (Quentin et al., 2005). Gender differences exist in nutrient requirements, with males growing faster (e.g. Bokkers and Koene, 2002) and thus requiring higher nutrient levels.
FE12			B	Preference for low protein/high energy diet (Siegel et al., 1997)	Preference for low protein/high energy diet (Siegel et al., 1997)		
FE13			C	Preference for low protein/high energy diet (Siegel et al., 1997)	Preference for low protein/high energy diet (Siegel et al., 1997)		
FE14			D	Preference for low protein/high energy diet (Siegel et al., 1997)	Preference for low protein/high energy diet (Siegel et al., 1997)		
FE15		*Crude protein content*	0-3 wk	23 % per kg of diet, with ME diet = 3200 kcal/kg diet (NRC, 1994)	23 % per kg of diet, with ME diet = 3200 kcal/kg diet (NRC, 1994)	23 % per kg of diet, with ME diet = 3200 kcal/kg diet (NRC, 1994)	Fast growing broilers need higher protein concentrations in their diet than slower growing broilers in order to maintain high growth rate, and protein requirement can be deduced from potential rate of protein deposition (Morris and Njuru, 1990).
FE16			3-6 wks	20 % per kg diet, with ME diet = 3200 kcal/kg diet (NRC, 1994)	20 % per kg diet, with ME diet = 3200 kcal/kg diet (NRC, 1994)	20 % per kg diet, with ME diet = 3200 kcal/kg diet (NRC, 1994)	

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
FE17			6-8 wks	18 % per kg diet, with ME diet = 3200 kcal/kg diet (NRC, 1994)	18 % per kg diet, with ME diet = 3200 kcal/kg diet (NRC, 1994)	18 % per kg diet, with ME diet = 3200 kcal/kg diet (NRC, 1994)	
FE18	**Amino acids**	*Arginine*	0-3 wks	1.25 % per kg diet (NRC, 1994); 105 % of lysine requirement (Emmert and Baker, 1997)			
FE19			3-6 wks	1.10 % per kg diet (NRC, 1994); 108 % of lysine requirement (Emmert and Baker, 1997)			
FE20			6-8 wks	1.00 % per kg diet (NRC, 1994); 108 % of lysine requirement (Emmert and Baker, 1997)			
FE21		*Glycine + Serine*	0-3 wks	1.25 % per kg diet (NRC, 1994)			
FE22			3-6 wks	1.14 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE23			6-8 wks	0.97 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE24		*Histidine*	0-3 wks	0.35 % per kg diet (NRC, 1994)			
FE25			3-6 wks	0.32 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE26			6-8 wks	0.27 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE27		*Isoleucine*	0-3 wks	0.80 % per kg diet (NRC, 1994)			
FE28			3-6 wks	0.73 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE29			6-8 wks	0.62 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE30		*Leucine*	0-3 wks	1.20 % per kg diet (NRC, 1994)			
FE31			3-6 wks	1.09 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE32			6-8 wks	0.93 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE33		*Lysine*	0-3 wks	1.10 % per kg diet (NRC, 1994); 1.12 % per kg diet for male broilers (Emmert and Baker, 1997); 1.48 % per kg diet for first week (Gous, 2010)			
FE34			3-6 wks	1.00 % per kg diet (NRC, 1994); 0.89 % per kg diet for male broilers (Emmert and Baker, 1997)			
FE35			6-8 wks	0.85 % per kg diet (NRC, 1994); 0.76 % per kg diet for male broilers (Emmert and Baker, 1997)			
FE36		*Methionine*	0-3 wks	0.50 % per kg diet (NRC, 1994); 36 % of lysine requirement (Emmert and Baker, 1997)			
FE37			3-6 wks	0.38 % per kg diet (NRC, 1994); 37 % of lysine requirement (Emmert and Baker, 1997)			
FE38			6-8 wks	0.32 % per kg diet (NRC, 1994); 37 % of lysine requirement (Emmert and Baker, 1997)			
FE39		*Methionine + Cystine*	0-3 wks	0.90 % per kg diet (NRC, 1994); 72 % of lysine requirement (Emmert and Baker, 1997)			

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
FE40			3-6 wks	0.72 % per kg diet (NRC, 1994); 75 % of lysine requirement (Emmert and Baker, 1997)			
FE41			6-8 wks	0.60 % per kg diet (NRC, 1994); 75 % of lysine requirement (Emmert and Baker, 1997)			
FE42		*Phenylalanine*	0-3 wks	0.72 % per kg diet (NRC, 1994)			
FE43			3-6 wks	0.65 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE44			6-8 wks	0.56 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE45		*Phenylalanine + Tyrosine*	0-3 wks	1.34 % per kg diet (NRC, 1994)			
FE46			3-6 wks	1.22 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE47			6-8 wks	1.04 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE48		*Proline*	0-3 wks	0.60 % per kg diet (NRC, 1994)			
FE49			3-6 wks	0.55 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE50			6-8 wks	0.46 % per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE51		*Threonine*	0-3 wks	0.80 % per kg diet (NRC, 1994); 67 % of lysine requirement (Emmert and Baker, 1997)			
FE52			3-6 wks	0.74 % per kg diet (NRC, 1994); 70 % of lysine requirement (Emmert and Baker, 1997)			
FE53			6-8 wks	0.68 % per kg diet (NRC, 1994); 70 % of lysine requirement (Emmert and Baker, 1997)			
FE54		*Tryptophan*	0-3 wks	0.20 % per kg diet (NRC, 1994)			
FE55			3-6 wks	0.18 % per kg diet (NRC, 1994)			
FE56			6-8 wks	0.16 % per kg diet (NRC, 1994)			
FE57		*Valine*	0-3 wks	0.90 % per kg diet (NRC, 1994); 77 % of lysine requirement (Emmert and Baker, 1997)			
FE58			3-6 wks	0.82 % per kg diet (NRC, 1994); 80 % of lysine requirement (Emmert and Baker, 1997)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE59			6-8 wks	0.70 % per kg diet (NRC, 1994); 80 % of lysine requirement (Emmert and Baker, 1997)			
FE60	**Fatty acids**	*Linoleic acid*	0-3 wks	1.00 % per kg diet (NRC, 1994)			
FE61			3-6 wks	1.00 % per kg diet (NRC, 1994)			
FE62			6-8 wks	1.00 % per kg diet (NRC, 1994)			
FE63	**Macrominerals**	*Calcium*	0-3 wks	1.00 % per kg diet (NRC, 1994)			Ratio calcium/phospor: 2.2 to 2.3 (Animal Sciences Group, 2004). The calcium requirement may be increased when diets contain high levels of phytate phosphorus (NRC, 1994).
FE64			3-6 wks	0.90 % per kg diet (NRC, 1994)			The calcium requirement may be increased when diets contain high levels of phytate phosphorus (NRC, 1994)
FE65			6-8 wks	0.80 % per kg diet (NRC, 1994)			The calcium requirement may be increased when diets contain high levels of phytate phosphorus (NRC, 1994)
FE66		*Chlorine*	0-3 wks	0.20 % per kg diet (NRC, 1994)			
FE67			3-6 wks	0.15 % per kg diet (NRC, 1994)			
FE68			6-8 wks	0.12 % per kg diet (NRC, 1994)			
FE69		*Magnesium*	0-3 wks	600 mg per kg diet (NRC, 1994)			

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
FE70			3-6 wks	600 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE71			6-8 wks	600 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE72		*Nonphytate phosphorus*	0-3 wks	0.45 % per kg diet (NRC, 1994)			
FE73			3-6 wks	0.35 % per kg diet (NRC, 1994)			
FE74			6-8 wks	0.30 % per kg diet (NRC, 1994)			
FE75		*Potassium*	0-3 wks	0.30 % per kg diet (NRC, 1994)			
FE76			3-6 wks	0.30 % per kg diet (NRC, 1994)			
FE77			6-8 wks	0.30 % per kg diet (NRC, 1994)			
FE78		*Sodium*	0-3 wks	0.20 % per kg diet (NRC, 1994)			
FE79			3-6 wks	0.15 % per kg diet (NRC, 1994)			
FE80			6-8 wks	0.12 % per kg diet (NRC, 1994)			

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
FE81	**Trace minerals**	*Copper*	0-3 wks	8 mg per kg diet (NRC, 1994)			
FE82			3-6 wks	8 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE83			6-8 wks	8 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE84		*Iodine*	0-3 wks	0.35 mg per kg diet (NRC,1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE85			3-6 wks	0.35 mg per kg diet (NRC,1994)			
FE86			6-8 wks	0.35 mg per kg diet (NRC,1994)			
FE87		*Iron*	0-3 wks	80 mg per kg diet (NRC, 1994)			
FE88			3-6 wks	80 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE89			6-8 wks	80 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE90		*Manganese*	0-3 wks	60 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE91			3-6 wks	60 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE92			6-8 wks	60 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE93		*Selenium*	0-3 wks	0.15 mg per kg diet (NRC,1994)			
FE94			3-6 wks	0.15 mg per kg diet (NRC,1994)			
FE95			6-8 wks	0.15 mg per kg diet (NRC,1994)			
FE96		*Zinc*	0-3 wks	40 mg per kg diet (NRC, 1994)			
FE97			3-6 wks	40 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE98			6-8 wks	40 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE99		*Fluor*	all				Essential dietary component (Animal Sciences Group, 2004) but recommended dietary values were not found.
FE100	**Fat-soluble vitamins**	*A (retinol)*	0-3 wks	1500 IU per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE101			3-6 wks	1500 IU per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE102			6-8 wks	1500 IU per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE103		*D_3 (cholecalciferol)*	0-3 wks	200 IU per kg diet (NRC, 1994)			
FE104			3-6 wks	200 IU per kg diet (NRC, 1994)			
FE105			6-8 wks	200 IU per kg diet (NRC, 1994)			
FE106		*E (tocopherol)*	0-3 wks	10 IU per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE107			3-6 wks	10 IU per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE108			6-8 wks	10 IU per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE109		*K (menadione)*	0-3 wks	0.50 mg per kg diet (NRC,1994)			
FE110			3-6 wks	0.50 mg per kg diet (NRC,1994)			
FE111			6-8 wks	0.50 mg per kg diet (NRC, 1994)			
FE112	**Water-soluble vitamins**	*B_{12} (cyanocobalamin)*	0-3 wks	0.01 mg per kg diet (NRC,1994)			
FE113			3-6 wks	0.01 mg per kg diet (NRC,1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE114			6-8 wks	0.007 mg per kg diet (NRC,1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE115		*Biotin*	0-3 wks	0.15 mg per kg diet (NRC,1994)			
FE116			3-6 wks	0.15 mg per kg diet (NRC,1994)			
FE117			6-8 wks	0.12 mg per kg diet (NRC,1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE118		*Choline*	0-3 wks	1300 mg per kg diet (NRC,1994)			
FE119			3-6 wks	1000 mg per kg diet (NRC,1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE120			6-8 wks	750 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE121		*Folacin*	0-3 wks	0.55 mg per kg diet (NRC,1994)			
FE122			3-6 wks	0.55 mg per kg diet (NRC,1994)			
FE123			6-8 wks	0.50 mg per kg diet (NRC,1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE124		*Niacin*	0-3 wks	35 mg per kg diet (NRC, 1994)			
FE125			3-6 wks	30 mg per kg diet (NRC, 1994)			
FE126			6-8 wks	25 mg per kg diet (NRC, 1994)			

Code	Specification of Need	Requirement	Life Stage	Quantification fast	Quantification medium	Quantification slow	Explanation
FE127		*B_5 (pantothenic acid)*	0-3 wks	10 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE128			3-6 wks	10 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE129			6-8 wks	10 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE130		*B_6 (pyridoxine)*	0-3 wks	3.5 mg per kg diet (NRC, 1994)			
FE131			3-6 wks	3.5 mg per kg diet (NRC, 1994)			
FE132			6-8 wks	3.0 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE133		*B_2 (riboflavin)*	0-3 wks	3.6 mg per kg diet (NRC, 1994)			
FE134			3-6 wks	3.6 mg per kg diet (NRC, 1994)			
FE135			6-8 wks	3.0 mg per kg diet (NRC, 1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE136		*B_1 (thiamin)*	0-3 wks	1.80 mg per kg diet (NRC,1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE137			3-6 wks	1.80 mg per kg diet (NRC,1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE138			6-8 wks	1.80 mg per kg diet (NRC,1994)			Estimate based on values obtained for other ages or related species (NRC, 1994).
FE139		*B3 (nicotinic acid)*	all				Essential dietary component (Animal Sciences Group, 2004) but recommended dietary values were not found.
FE140		*Folic acid*	all				Essential dietary component (Animal Sciences Group, 2004) but recommended dietary values were not found.
FE141		*Ascorbic acid*	all				Essential dietary component (Animal Sciences Group, 2004) but recommended dietary values were not found.
FE142	**Development of digestive system**	*Provision of sturdy particles*	AB	Small sturdy particles are taken up to aid in development of gizzard	Small sturdy particles are taken up to aid in development of gizzard	Small sturdy particles are taken up to aid in development of gizzard	Chickens ingest small-sized grit to aid in digestion of whole grains; this is however not necessary to digest pelleted feed (European Commission, 2000). Quantification of the amount of inedible particles necessary to ingest for full development of the gizzard was not found.
FE143		*Dietary fiber*	all	3 - 10 % insoluble fibers in diet (Hetland et al., 2004)	3 - 10 % insoluble fibers in diet (Hetland et al., 2004)	3 - 10 % insoluble fibers in diet (Hetland et al., 2004)	Soluble fiber fraction can retain water, leading to high viscosity in small intestine which inhibits digestion and decreases rate of passage. Digestion of soluble fibers affects intestinal microbiota. Insoluble fiber fraction is not digested and has no effect on intestinal microbiota, but can lead to increase of bulk in digestive tract, leading to expansion of intestinal components or increased passage rate. Moderate (3 - 10 %) addition of insoluble fibers to diets can improve nutrient digestion. Furthermore the size of the gizzard is positively correlated with amount of insoluble dietary fibers present in the diet (Hetland et al., 2004).
FE144		*Large feed particles*	all				Development of gizzard is influenced by particle size of food ingested early in life. When fed non-pelleted feedstuff the relative size of the gizzard is positively correlated with feed particle size (Amerah et al., 2007a). Furthermore larger feed particles stimulate development of the gizzard and gastric functions (e.g. secretion of digestive enzymes), in contrast to finely ground feed that easily passes through the gizzard. Enhancement of gastric functions is beneficial for preventing intestinal colonisation by feed-borne pathogens (Engberg et al., 2002). Diet of finely ground feed results in decrease of relative (i.e. in relation to body weight) overall length of digestive tract compared to diet containing large particles (Amerah et al., 2007b). Ideal feed particle size for development of digestive system of broilers was not found.
FE145	**Availability of water**	*Fresh water*	all				Drinking water should be fresh and of good quality, provided in clean drinking devices (ASG, 2004).
FE146		*Sufficient water supply*	all	Drinking is done directly after feeding (Siegel et al., 1997)	Drinking is done directly after feeding (Siegel et al., 1997)	Drinking is done directly after feeding (Siegel et al., 1997)	Quantification of the amount of water consumed by broilers was not found, however water should always be supplied abundantly to prevent dehydration.



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