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Contents

EDITORIAL

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This edition is focused on poultry welfare. Welfare aspects have become the dominating issue in animal production, and poultry plays a leading role in this debate.

The transition of laying hens from unlimited free-range systems to conventional cages in the 1960ies was driven by the control of infectious diseases and better bird performance.

Indeed, the cage system produced the lowest incidence of diseases and mortality. **However, concerns on health and mortality in chickens have been considered an economic issue rather than a welfare problem.**

In recent decades, the western society was not prepared to accept the extreme restriction of space and environmental stimuli in cages for ethical reasons (*see P. Kunzmann, 2011; Lohmann Information 46(1), p. 3-9*).

It may not seem appropriate to focus on animal welfare at a time when the world is dealing with the disastrous Covid 19 pandemic.

Planning of this edition has started long before the Covid 19 pandemic emerged and the present focus on this problem may not fundamentally change the attitude of our society to animal welfare. Therefore, we decided not to cease working on this issue.

Decisions on animal welfare should be based on scientific information. In the introductory article, U. Knierim and co-authors present the complex matter of welfare assessment under practical conditions and the interpretation of welfare indicators. The authors stress the importance of reliability of measurements and subjective scoring systems of animal- and resource-based indicators.

There is at present no generally accepted scientific system to assign weights to different welfare criteria to compute a comprehensive score of the level of welfare.

Views of experts, consumers or citizens may be used when discussing the ultimate question regarding the acceptable level of welfare.

Cavero and co-authors review actual problems in egg production systems. **Most problems are related to the behaviour of laying hens in non-cage systems, such as nervousness and smothering, floor eggs, feather pecking and cannibalism.** Alternatives to conventional molting methods and to killing day old layer male chicks are also discussed.

Bessei and co-authors report on changes in the production conditions of broilers and turkeys, which aim at improving the welfare status of the birds. Genetic selection has proved to be successful in reducing the incidence of leg damages and cardiovascular problems, like Ascites and Sudden Death Syndrome, and to a certain extent, footpad dermatitis.

The latter, however, is clearly a problem of wet litter and can be controlled by the use of adequate litter materials and ventilation rate. **Problems with stocking density, lighting programs and light quality are also treated in this article.**

Environmental enrichments have become the preferred subject in animal welfare research.

Two articles on this subject in this edition reflect this topic. W. Bessei reviews the theoretical background and expectations of enrichments in a general context and shows examples of the large variety of enrichments used in practical broiler and turkey production. **First estimates of the costs of enrichment are also presented.**

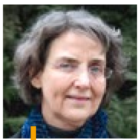
Julia Malchow reports results of three successive experiments where she investigated the use of elevated platforms by broiler breeds differing in growth rate. **There is a high motivation to use elevated platforms in all breeds.** Elevated platforms stimulate activity and walking ability and, thus, improve the birds' welfare.

The perception of animal welfare in the human population is subject to continuous development.

Retailers and consumers insist on information on the living conditions of animals used for meat production.

The present articles show that researchers and producers are prepared to develop measures and technical solutions to improve the welfare status of chickens and other poultry species under practical production conditions to meet the consumer's request.

Assessing and improving poultry welfare in commercial production systems



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She is Veterinary specialist in Animal Welfare and in Applied Animal Behaviour. Her research activities in national and European projects mainly concern poultry and cattle and include animal welfare assessment (with an emphasis on methodological questions), and how to improve welfare.

It includes assessments of the bodily state and behavioural responses of animals as affected by their physical and social environment including human-animal interactions, often applying an on-farm, epidemiological approach. Another focus is knowledge transfer between practice and science, but also on the level of different advisory boards.

ABSTRACT

Animal welfare is of growing concern in many countries. The objective of this article is to discuss why there are differing definitions and approaches to the assessment and improvement of animal welfare, whether differences matter and where there is general agreement in current scientific concepts.

Furthermore, future directions regarding on-farm welfare improvement are proposed. It is generally agreed that animal welfare refers to the multi-faceted physical as well as mental state of the individual animal and can range from very good to very poor.

In order to cover the multitude of relevant aspects, different approaches, and thus welfare definitions, are used. They commonly do not contradict each other, but approach welfare from slightly different perspectives or with different focal points.

For the assessment of welfare, a broad number of indicators must be used that may be either animal- or resource- and management-based.

In terms of validity, animal-based indicators are to be preferred, but due to feasibility aspects, often a mixture of different types of indicators are recommendable and used. The selection of individual welfare indicators is, however, not only based on scientific and feasibility criteria, but is also value-dependent.

This similarly applies to the interpretation of conflicting results regarding different measures. Transparency about the decision-making concerning measure selection and interpretation is therefore crucial.

When deciding about acceptable welfare levels, various human interests come on board, generating a societal debate.

The practical welfare assessment must be reliable in order to be useful and trustworthy, which requires considerable efforts. The assessment can serve different purposes, but most importantly provides poultry farmers useful information and starting points for improvement.

Many multifactorial welfare problems can only successfully be tackled by farm-specific, longer-term optimisation processes. Joint learning and knowledge sharing in networks of farmers together with other experts is a very promising approach for this.

While further knowledge about risk factors for welfare problems is still needed, practice-led innovations should also be stimulated. Moreover, continued methodical research is necessary to improve the choice and practicability of valid animal-based indicators for application in commercial production systems.

Keywords: animal welfare, welfare assessment, poultry production.

INTRODUCTION

Animal welfare is a topic that has been receiving increasing attention globally (e.g. OIE Global Animal Welfare Strategy, OIE 2021a), particularly in Western countries (e.g. EU-legislation on laying hens and broilers, EU 1999, 2007), and has led to many initiatives in the private sector to improve animal welfare.

Among the industry initiatives are labels or brands. Moreover, company differentiation may be aspired by applying animal welfare standards which are not necessarily made explicit, but are part of the companies' corporate social responsibility. Retailers' standards for their suppliers may not only stipulate enhanced management standards, but also ensure that products will only be purchased from certain production systems with high welfare standards, such as from non-cage or non-mutilated animals.

This is an increasing development, with globally acting retailers (such as Burger King or McDonald's) having substantial impacts on producers (Knierim and Pajor 2018, Bessei 2018).

Another approach is the so called "Initiative Tierwohl" (Animal Welfare Initiative) in Germany, organised by most retailers, processors and producers' associations.

Retailers pay a certain amount of money per kilogram of poultry into a fund, from which participating farmers receive a premium for adhering to certain welfare standards (Initiative Tierwohl, without year).

Also, voluntary agreements between industry and government have been established, like the German agreement on the ban of beak-trimming in laying hens (BMEL and ZDG 2015).

Considering the multitude of approaches and initiatives to the improvement of poultry welfare and the many actors with different motivations, it is not amazing that the actual understanding of animal welfare varies. This renders communication difficult. Therefore, it is the aim of this paper to briefly address these issues.

CONCEPTS OF ANIMAL WELFARE

Animal welfare is composed of many different aspects that determine the animal life's quality; thus, it is a multi-faceted or multidimensional state. In order to cover the multitude of relevant aspects, they are usually categorized. This can be done in different ways.

For example, the World Organisation for Animal Health OIE (2019) states in the Terrestrial Animal Health Code that "An animal experiences good welfare if the animal is healthy, comfortable, well nourished, safe, is not suffering from unpleasant states such as pain, fear and distress, and is able to express behaviours that are important for its physical and mental state."

This definition refers to two basic and often used categories, "physical and mental state", and concurrently mentions further operational categories which relate to the 'Five Freedoms' first mentioned by the British Brambell Committee in 1965 and codified by the Farm Animal Welfare Council (FAWC, 1979).

They encompass the freedom (1) from hunger or thirst, (2) from discomfort, (3) from pain, injury or disease, (4) to express (most) normal behaviour and (5) from fear and distress. It is important to understand that the welfare state of an animal gradually depends on the extent of these freedoms, that welfare is not an all-or-none issue, but a continuum from very poor to very good (Broom, 1988).

Broader categories are used in the German Animal Welfare Act (2006), stating that the life and well-being of animals shall be protected and that no pain, suffering or damage be inflicted on them without good reason. Thus, mental aspects are categorized into pain, suffering and well-being, and physical aspects into the life itself and damage.

Another sorting of the different aspects of welfare relates to societal welfare concerns. According to Fraser et al. (1997) they refer to the three dimensions: feelings, physical condition and naturalness. Ultimately, these different approaches intend to ensure that important aspects of welfare are not neglected.

The multidimensional nature of welfare (Figure 1) additionally is a reason for the different welfare definitions. At closer scrutiny, commonly they do not contradict each other, but approach the phenomenon from different angles.

Thus, with a few, mostly not very influential exceptions, there is no fundamental dissent between the different categorisations and definitions; however, they reflect somewhat different focal points or perspectives.

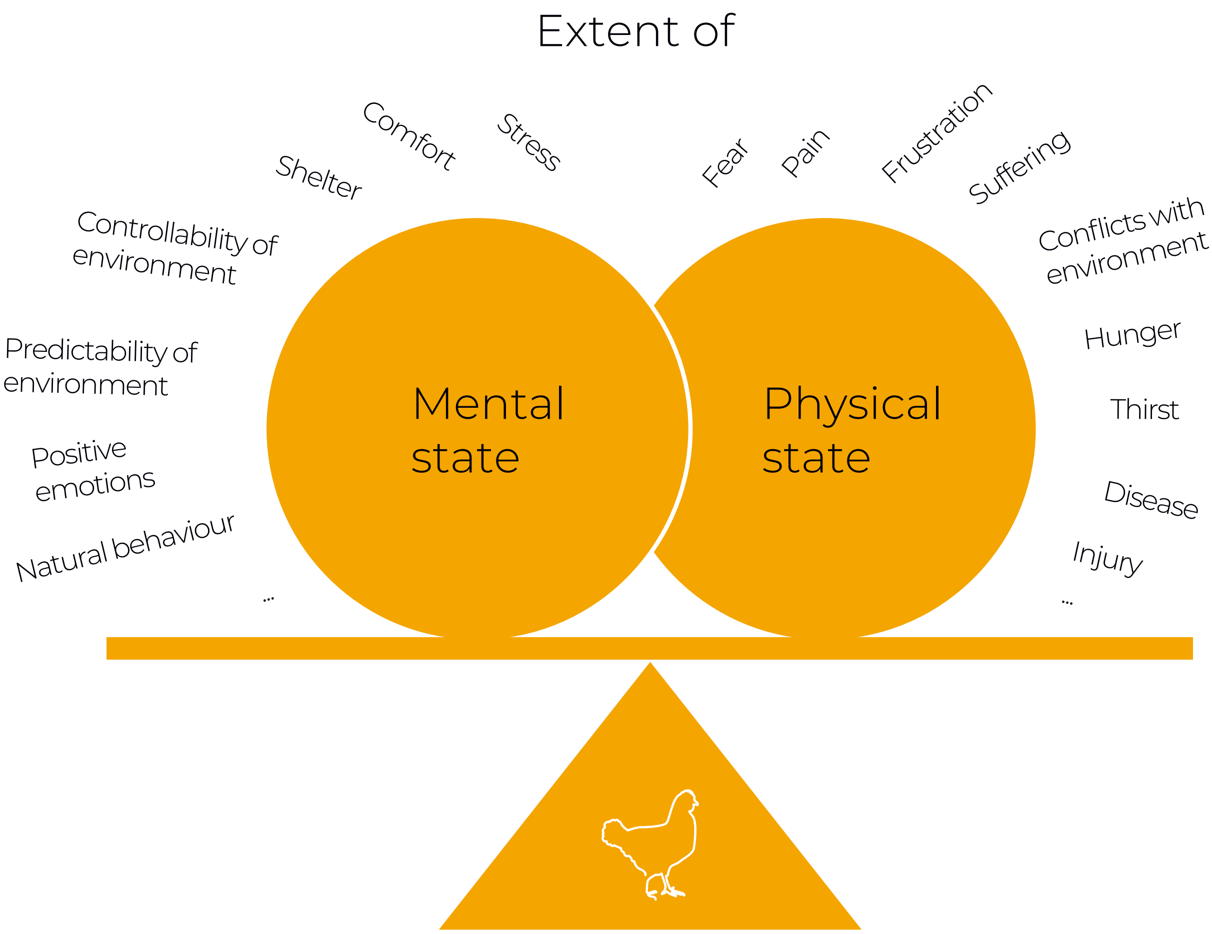


Figure 1.
Multidimensionality of poultry welfare which can range from very poor to very good

HOW TO ASSESS POULTRY WELFARE: SELECTION, APPLICATION AND INTERPRETATION OF MEASURES

Another important consequence of the multidimensionality of animal welfare is that it cannot be assessed based on one indicator alone. Depending on the question, a large number of measures should be applied (Fraser 1995, Knierim et al. 2001, OIE 2021b).

Animal welfare indicators can basically be divided into two different categories, each with different advantages and disadvantages: animal-based vs. resource- and management-based measures.

When choosing welfare measures or indicators, the main concern (besides feasibility) is validity of the measure (Knierim and Winckler, 2009). Therefore, animal-based measures that directly provide information about the state of the animals should in principle be preferred (Johnsen et al. 2001, Whay et al. 2007).

Examples are plumage, skin, keel bone or foot pad condition, body weight, mortality rate or fear responses, water consumption or use of different resources. Another advantage of animal-based criteria in welfare standards is that they allow the farmer freedom in which way they reach the set goal.

On the other hand, animal-based measures are still saddled with a number of methodical challenges (e.g. Rushen and de Passillé 1992, Knierim and Winckler 2009, Mullan et al. 2009) and are in general more difficult and costly to implement (particularly behaviour measures). This is probably the main reason why animal-based measures are still underused, and why most animal-based measures are related to animal health (e.g. Zapf et al. 2017).

Health indicators that are recorded routinely (e.g. mortality or certain pathologies in slaughter records), or that can be recorded in an automated way at a bottleneck such as the slaughterhouse (e.g. foot pad lesions in poultry) are likely candidates. Particularly health measures that give information about longer-term welfare states are of special interest (Grandin 2017). Nevertheless, it must be considered that disease causes may be sometimes outside the control of the farmer. Additionally, it might be necessary to grant sufficient time for reaching improvements.

In the past and still in current legislation or standards, resource- and management-based measures such as type of housing system, stocking density, light, feed, water or litter provision were and are predominantly used. Mostly they are easier to apply, but their effect on the animals depends on interactions with other factors and preconditions on the side of the animal (genetics, earlier experience) (Butterworth et al. 2011, Veissier et al. 2012).

These measures are less valid concerning the welfare state of the animals (Waiblinger et al. 2001), and their use alone does not provide sufficient animal welfare information.

Figure 2. Plumage condition is an important indicator of feather pecking and should be regularly checked by the farm staff (by courtesy Christiane Keppler)

Nevertheless, resource- and management-based criteria, such as access to free range or use of non-cage systems, are easier to communicate to the public, compared to e.g. certain limits of mortality rates or lameness prevalence. Moreover, the absence of resources may render certain animal-based measures redundant; for instance when perches are lacking, it needs not to be observed whether birds do perch.

On the other hand, when resources are available, quality and availability of the resources and interactions with other factors such as lighting or rearing experience will affect the actual behavioural freedom or possibly cause behavioural problems.

In recent welfare assessment protocols (e.g. Welfare Quality® 2009, Knierim et al. 2020), a combination of the different types of measures with a preference for animal-based measures is used. Resource- and management-based measures are mostly intended to cover certain behavioural aspects, while animal-based measures refer mainly to health aspects.

In addition, some health measures are truly indirect measures of behavioural problems, such as plumage condition as an indicator of feather pecking (Gunnarsson et al. 1995, Tauson et al. 2005) (Figure 2).

A further important criterion of validity is reliability. For systematic reasons it is usually addressed separately. Here it is asked whether measurement results are reproducible between and within assessors or over time (Knierim and Winckler 2009). In principle, deviations between measurements can occur in all types of data collection – even in the case of a length measurement, when using unclear measuring instructions or when reading errors occur.

However, errors are the greater, the more complex the measurement is and the more they include subjective judgements (e.g. of the dimension or colour of a skin lesion, etc.). Apart from divergent judgements, perceptual abilities, personal experience and expectations may bias measurements (Vasseur et al. 2013).

In terms of quality assurance, it is important to keep the measurement error as low as possible. For instance, the results of farm audits in animal welfare programmes should be consistent between assessors (Mullan et al. 2011). To ensure that results can be reproduced by different assessors, precise measurement instructions, sufficient training and reliability testing are necessary (Knierim 2013).

If sufficient reliability is not achieved, it must be improved by refining the definitions, changing the observation methods and/or assessment categories, or by additional training. It may often help to combine different categories (March et al. 2007), observe fewer animals at a time, or provide better lighting for assessments of skin or plumage. It may also happen that a person is not suitable for data collection, because he or she is near-sighted or has other limitations of perception.

Sufficient reliability is indispensable, otherwise results will not be trustworthy. This is not only decisive in scientific studies, but also in welfare monitoring where management decisions shall be based on the results, or where they are used for benchmarking or auditing.

Ideally, reliability should not only be assessed initially, but re-checked at certain intervals, since the assessments can change with increasing experience (Vasseur et al. 2013). This is particularly important when several people are involved. Unfortunately, reliability testing is often neglected, partly because it can be rather complicated.

A sufficient number of independent samples is needed, and the different behavioural or health categories should be represented as evenly as possible (Mullan et al. 2011, Knierim 2013).

INTERPRETATION OF WELFARE INDICATORS

The selection of welfare measures is not only affected by validity, reliability and feasibility criteria, but also by professional, ethical, cultural, or social background and possibly economic considerations. In addition, the interpretation of conflicting results regarding different indicators is difficult (Fraser 2003).

An example is the overall welfare assessment of hens with free-range access that show less feather pecking (Jung and Knierim 2018), but a higher mortality rate (Häne et al. 2000) than hens without free-range access.

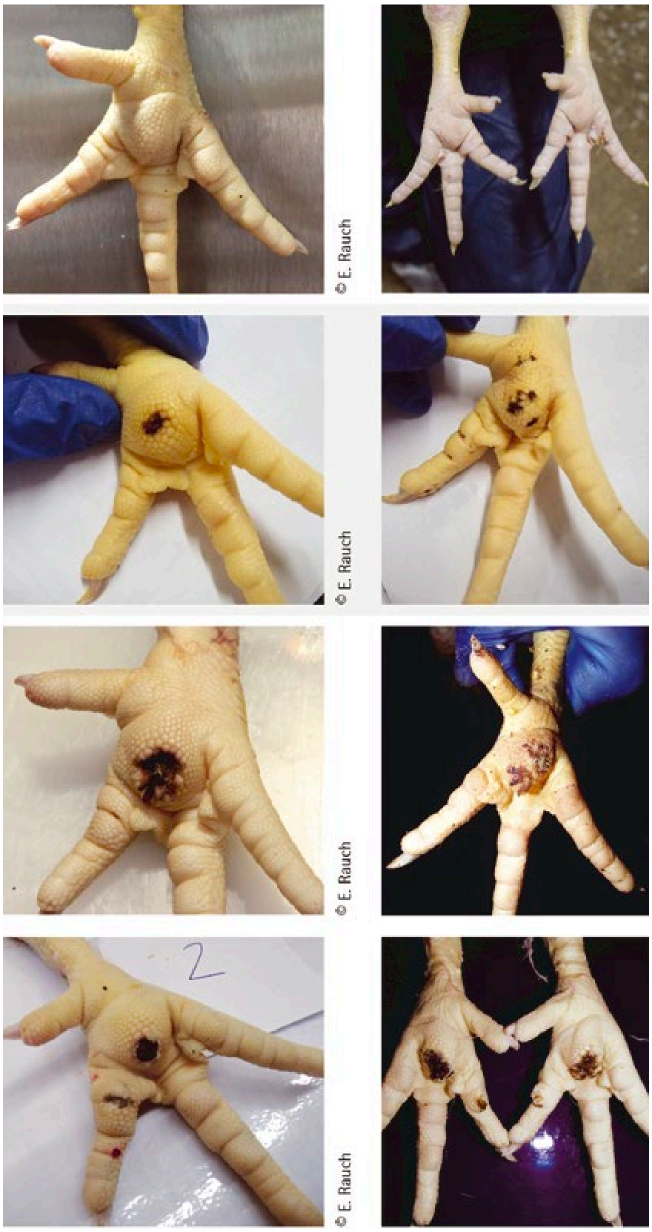
In such a conflicting case a greater number of additional measures should be included. However, the principal challenge is, that there is no scientific basis today and likely not in the future for the decision on the relative importance of the individual indicators (Fraser 2003). Therefore, it is crucial to provide transparency about the decision on the selection and interpretation of different welfare measures.

Regarding interpretation, it can be decided to allocate the same weight to all indicators (e.g. KTBL 2006), or to base weightings on majority views of experts (e.g. Boutreau et al. 2009), consumers or citizens.

The final decision, about which level of welfare is acceptable or should be reached, is even more dependent on subjective judgements and should be based on a societal debate.

Here various human interests, regarding e.g. economy, human health, labour safety or environmental protection come on board and have to be weighed against the assumed animal interests.

ANIMAL WELFARE ASSESSMENT IN PRACTICE



Welfare indicators may be recorded by the farmers themselves, by veterinarians or other advisors, by automatic means and at the 'bottleneck' slaughterhouse (Grafl et al. 2017, Louton et al. 2018). The latter allows easy inspection of a high number of animals or even the whole flock and provides retrospective information about on-farm welfare, as long as the indicators assessed are not unduly influenced by catching and transport. Slaughter records commonly include figures on dead on arrivals, cachexia, pathological changes like ascites and organ abnormalities (Starosta 2015).

Figure 3.

Scoring scheme for footpad dermatitis in broilers (Knierim et al. 2020)

Top: Score 0 No foot pad lesions: at maximum slight discoloration

2nd row: Score 1 Slight foot pad lesions: up to pea-sized (<0.5 cm longest diameter) dark discoloration or destruction of the upper skin layer

3rd and 4th row: Score 2 Severe foot pad lesions: at minimum pea-sized (≥0.5 cm longest diameter) dark discoloration or destruction of the upper skin layer

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However, often reliability of recording is poor. An important future task is a better standardisation of welfare assessments at the slaughterhouse (Louton et al. 2018). To lesser degree, this also applies to the frequently applied automatic detection of footpad dermatitis in broilers (Lund et al. 2017) in fulfilment of the EU directive (EU 2007).

Automatic detection of footpad dermatitis is also commercially used in turkeys and ducks, and could be extended to laying hens and broiler breeders. Further welfare indicators with a potential for automatic recording at the slaughterhouse are feather damage (laying hens, broilers, broiler breeders, turkeys), skin lesions (laying hens, broilers, broiler breeders, turkeys, ducks), including hock burns (broiler, turkeys, ducks) and keel bone damage (laying hens, Jung et al. 2021) (Figure 4).

However, automatic recording is also possible at the farm. Precision livestock farming systems (PLF) may help to improve animal welfare through providing continuous welfare information (Rowe et al. 2019) for whole flocks and possibly through establishment of early warning systems which may alert farmers to potentially upcoming problems so that they can adopt early preventive measures.

Technical progress will certainly increase options to monitor animal welfare on-farm and contribute to welfare improvements considerably. However, care should be taken not to neglect human control and interaction with the animals, and to avoid negative effects on the human-animal relationship which is also an important welfare factor (Zulkifli 2013). For stockpeople who are more animal- than technology-oriented, it may even impair labour quality.

Figure 4.

Example of a 3D image of a laying hen carcass with focus on the keel bone for the automatic monitoring of keel bone damage. This monitoring at the bottleneck slaughterhouse opens up opportunities to better combat poultry welfare problems in the long term.

HOW TO IMPROVE WELFARE

A large body of animal welfare research is dedicated to assess effects of certain housing or management conditions on animal welfare and to unravel causes of welfare problems. Many poultry welfare problems such as feather pecking, cannibalism or keel bone damage are long-standing subjects of research due to their challenging multifactorial nature.

This research contributes significantly to the growing knowledge about risk factors for welfare, but successful transfer of results into farm practice is limited. Barriers are not only lacking knowledge transfer into practice (Jung and Knierim 2018), but also economic and organisational constraints concerning implementation.

The high number of contributing factors and their quality and interactions vary from farm to farm. The application of only a single measure, e.g. provision of more litter of better quality to prevent feather pecking problems, seldom leads to profound improvement.

Although the preventive effect of friable litter is scientifically well established (Jung and Knierim 2018) there are individual farms that have a rather poor litter quality, but no feather pecking problem. To investigate associations between potential risk factors and welfare problems under real farm conditions, epidemiological studies have been increasingly undertaken (see overview for feather pecking in Jung and Knierim 2018).

Altogether they confirm the multifactorial cause of many problems and the potentially variable outcomes at farm level. Therefore, we conclude that individual monitoring of the respective welfare outcomes on-farm is an important precondition for welfare improvement. It enables the farmer (potentially together with an advisor) to decide whether action is needed and to assess its effectiveness (Zapf et al. 2017).

If welfare problems or possible risk factors are identified, steps of improvement should be tailored to the specific farm (Lambton et al. 2013).

This process may be even more successful, when not performed in the classical form of advice to the farmer, but as joint learning and knowledge sharing among farmers and other experts (e.g. van Dijk et al. 2019). Such networks do not only largely motivate participating farmers, but the transdisciplinary exchange considerably contributes to a general aggregation of knowledge and to valuable innovations in practice.

Although, change of single factors may often not lead to expected improvements on individual farms, the number of fulfilled preventive measures appears to matter. With regard to feather pecking farms implementing more recommended measures, achieve a better outcome (Lambton et al. 2013, Jung and Knierim 2019).

For further welfare problems, this has yet to be investigated. Regarding catching, transport and slaughter, similar principles as outlined above apply, and in general, potential welfare problems during these last stages of a bird's life should not be neglected (e.g. EFSA, 2011).

CONCLUSIONS

Animal welfare is a multi-faceted state of the animal. This needs to be taken into account when assessing welfare by using a variety of, preferentially animal based, welfare indicators.

Animal welfare assessment on-farm or at the slaughterhouse provides poultry farmers with useful information about their flocks and starting points for improvement.

Regardless of the purpose of assessment, its reliability is of great importance and should receive more attention.

Many multifactorial welfare problems can only successfully be tackled by farm-specific, longer-term optimisation processes, for which joint learning and knowledge sharing in networks of farmers together with other experts is a very promising approach.

While further knowledge about risk factors for welfare problems is still needed, practice-led innovations should also be stimulated. Moreover, continued methodical research is necessary to improve the choice and practicability of valid animal-based indicators for application in commercial production systems.

References. *Bessei, W. (2018) Impact of animal welfare on worldwide poultry production. World's Poultry Science Journal 74: 211-224.*

BMEL and ZDG (2015) Vereinbarung zur Verbesserung des Tierwohls, insbesondere zum Verzicht auf das Schnabelkürzen in der Haltung von Legehennen und Mastputen. https://www.bmel.de/SharedDocs/Downloads/DE/Broschueren/EineFragederHaltungTierwohl.pdf?__blob=publicationFile&v=2 (accessed 5 January 2021).

Botreau, R., I. Veissier and P. Perny (2009) Overall assessment of animal welfare: strategy adopted in Welfare Quality®. Animal Welfare 18: 363-370.

Brambell, F.W. (ed.) (1965) Report of the Technical Committee to enquire into the welfare of animals kept under intensive livestock husbandry systems. Her Majesty's Stationary Office, London.

Broom, D.M. (1988) The scientific assessment of animal welfare. Applied Animal Behaviour Science 20: 5-19.

Butterworth, A., J.A. Mench and N. Wielebnowski (2011) Practical strategies to assess (and improve) welfare. In: Appleby, M.C., J.A. Mench, I.A.S. Olsson and B.O. Hughes (eds.): Animal welfare (2nd ed.): p. 200-214. CABI, Wallingford, UK.

EFSA (2011) Scientific Opinion Concerning the Welfare of Animals during Transport. EFSA Journal 9: 1966-2091.

EU (1999) EU Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. Official Journal L 203: 53-57.

EU (2007) Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production Official Journal L 182: 19-28.

FAWC (1979) Farm Animal Welfare Council Press Statement. https://webarchive.nationalarchives.gov.uk/20121010012427/http://www.fawc.org.uk/freedoms.htm (accessed 5 January 2021).

Fraser, D. (1995) Science, values and animal welfare: exploring the 'inextricable connection'. Animal Welfare 4: 103-117.

Fraser, D. (2003) Assessing animal welfare at the farm or group level. The interplay of science and values. Animal Welfare 12: 433-443.

Fraser, D., D.M. Weary, E.A. Pajor and B.N. Milligan (1997) A Scientific Conception of Animal Welfare that Reflects Ethical Concerns. Animal Welfare 6: 187-220.

German Animal Welfare Act (2006) Tierschutzgesetz as of 18 May 2006 (BGBl. I p. 1206, 1313), last amended by Article 280 of the regulation from 19 June 2020 (BGBl. I p. 1328).

Grafl, B., S. Polster, T. Sulejmanovic, B. Pürrer, B. Guggenberger and M. Hess (2017) Assessment of health and welfare of Austrian laying hens at slaughter demonstrates influence of husbandry system and season. British Poultry Science 58: 209-215.

Grandin, T. (2017) On-farm conditions that compromise animal welfare that can be monitored at the slaughter plant. Meat Science 132: 52-58.

Gunnarsson, S., K. Oden, B. Algers, J. Svedberg and L.J. Keeling (1995) Poultry health and behaviour in a tiered system for loose housed layers. Dept. of Animal Hygiene, SLU, Skara, Sweden Report 35. Häne, M., B. Huber-Eicher and E. Fröhlich (2000) Survey of laying hen husbandry in Switzerland. World's Poultry Science Journal, 56: 21-31.

Initiative Tierwohl (without year) https://initiative-tierwohl.de/ (accessed 5 January 2021).

Johnsen, P. F., T. Johannesson and P. Sandoe (2001) Assessment of farm animal welfare at herd level - Many goals, many methods. Acta Agricultura Scandinavica A 30: 26-33.

Jung, L. and U. Knierim (2018) Are practice recommendations for the prevention of feather pecking in laying hens in non-cage systems in line with the results of experimental and epidemiological studies? Applied Animal Behaviour Science 200: 1-12.

Jung, L. and U. Knierim (2019) Differences between feather pecking and non-feather pecking laying hen flocks regarding their compliance with recommendations for the prevention of feather pecking – A matched concurrent case-control design. Applied Animal Behaviour Science 219: https://doi.org/10.1016/j.applanim.2019.104839. Jung, L., A. Nasirahmadi, J. Schulte-Landwehr and U. Knierim (2021) Automatic assessment of keel bone damage in laying hens at the slaughter line. Animals 11, 163. https://doi.org/10.3390/ani11010163.

Jung, L., A. Nasirahmadi, J. Schulte-Landwehr and U. Knierim (2021) Automatic assessment of keel bone damage in laying hens at the slaughter line. Animals 11, 163. https://doi.org/10.3390/ani11010163.

Knierim, U. (2013) Qualitätssicherung bei ethologischen Untersuchungen – der Aspekt der Reliabilität. In: Aktuelle Arbeiten zur artgemäßen Tierhaltung 2013, KTBL-Schrift 503: 97–105, KTBL, Darmstadt, Germany.

Knierim, U. and C. Winckler (2009) On-farm welfare assessment in cattle – validity, reliability and feasibility issues and future perspectives with special regard to the Welfare Quality® approach. Animal Welfare 18: 451-458.

Knierim, U. and E.A. Pajor (2018) Regulation, enforcement and incentives. In: Appleby, M.C., I.A.S. Olsson and F. Galindo (eds): Animal welfare. (3rd ed.) p. 349-361. CABI: Wallingford, UK.

Knierim, U., D. Gieseke, S. Michaelis, C. Keppler, B. Spindler, E. Rauch, S. Petermann, R. Andersson, U. Schultheiß and R. Zapf (2020).

Tierschutzindikatoren: Leitfaden für die Praxis – Geflügel. (2nd ed.) KTBL: Darmstadt, Germany.

Knierim, U., C.S. Carter, D. Fraser, K. Gärtner, S.K. Lutgendorf, S. Mineka, J. Panksepp and N. Sachser (2001) Good Welfare: Improving Quality of Life. In: Broom, D.M. (ed): Coping with Challenge: Welfare in Animals including Humans. p. 79-100, Dahlem University Press, Berlin, Germany.

KTBL (2006) Nationaler Bewertungsrahmen Tierhaltungsverfahren. KTBL-Schrift 446. KTBL, Darmstadt, Germany.

Lambton, S., C.J. Nicol, M. Friel, D.C.J. Main, J.L. McKinstry, C.M. Sherwin, J. Walton and C.A. Weeks (2013) A bespoke management package can reduce the levels of injurious pecking in loose housed laying hen flocks. Veterinary Record 172: 423-430.

Louton, H., M. Erhard and A.-C. Wöhr (2018) Acquisition of animal-based welfare measures at slaughter of poultry. Fleischwirtschaft 11: 94-98.

Lund, V. P., L. R. Nielsen, A. R. S. Oliveira and J. P. Christensen (2017) Evaluation of the Danish footpad lesion surveillance in conventional and organic broilers: Misclassification of scoring. Poultry Science 96: 2018-2028.

March, S., J. Brinkmann und C. Winckler (2007) Effect of training on the inter-observer reliability of lameness scoring in dairy cattle. Animal Welfare 16: 131-133.

Mullan, S., S. A. Edwards, A. Butterworth, H. R. Whay and D.C.J. Main (2011) Inter-observer reliability testing of pig welfare outcome measures proposed for inclusion within farm assurance schemes. The Veterinary Journal 190: 100-109.

Mullan, S., W.J. Browne, S.A. Edwards, A. Butterworth, H.R. Whay and D.C.J. Main (2009) The effect of sampling strategy on the estimated prevalence of welfare outcome measures on finishing pig farms. Applied Animal Behaviour Science 119: 39-48.

OIE (World Organisation for Animal Health) (2019) Terrestrial Animal Health Code. Introduction to the recommendations for animal welfare. https://www.oie.int/fileadmin/Home/eng/Health_standards/tahc/current/chapitre_aw_introduction.pdf (accessed 5 January 2021).

OIE (World Organisation for Animal Health) (2021) The OIE global animal welfare strategy. https://www.oie.int/en/animal-welfare/oie-standards-and-international-trade (accessed 5 January 2021).

Rowe, E., M.S. Dawkins and S.G. Gebhardt-Henrich (2019) A systematic review of precision livestock farming in the poultry sector: Is technology focussed on improving bird welfare? Animals 9: 614-632.

Rushen, J. and A.M.B. de Passillé (1992) The scientific assessment of the impact of housing on animal welfare: a critical review. Canadian Journal of Animal Science 72: 721-743.

Starosta, S. (2015) Potenziale derzeitiger Befunderhebung – Verwendung der offiziellen Schlachttier- und Fleischuntersuchungsstatistik für einen Monitoring-Bericht der Tiergerechtheit. Thünen Working Paper 46, Braunschweig, Germany.

Tauson, R., J. Kjaer, G.A. Maria, R. Cepero and K.E. Holm (2005) Applied scoring of integument and health in laying hens. Animal Science Papers Reports 23: 153-159.

van Dijk, L., H.J. Buller, H.J. Blokhuis, T. van Niekerk, E. Voslarova, X. Manteca, C.A. Weeks and D.C.J. Main (2019) Hennovation: Learnings from promoting practice-led multi-actor innovation networks to address complex animal welfare challenges within the laying hen industry. Animals 9, 24; doi:10.3390/ani9010024.

Vasseur, E., J. Gibbons, J. Rushen and A.M. de Passillé (2013) Development and implementation of a training program to ensure high repeatability of body condition scoring of dairy cows. Journal of Dairy Science 96: 4725-4737.

Veissier, I., A. Aubert and A. Boissy (2012) Animal Welfare - A result of animal background and perception of its environment. Animal Frontiers 2: 7-15.

Waiblinger, S., U. Knierim and C. Winckler (2001) Development of an on-farm welfare assessment system in dairy cows using an epidemiological approach. Acta Agricultura Scandinavica A 30: 73-77.

Welfare Quality (2009) Welfare Quality® assessment protocol for poultry. Welfare Quality® consortium, Lelystad, The Netherlands.

Whay, H. R. (2007) The journey to animal welfare improvement. Animal Welfare 16: 117-122.

Zapf, R., U. Schultheiß, U. Knierim, J. Brinkmann and L. Schrader (2017) Assessing farm animal welfare – guidelines for on-farm self-assessment. Landtechnik 72: 214-220.

Zulkifli, I. (2013) Review of human-animal interactions and their impact on animal productivity and welfare. Journal of Animal Science and Biotechnology 4: 25-31.

WELFARE ASPECTS IN EGG PRODUCTION

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ABSTRACT

Animal welfare has become a major issue of poultry production in industrial countries.

Government authorities, NGOs, retailers and consumers raise concern about intensive livestock production systems, in particular those used for egg production. The main points of concern of conventional cages are the restricted space and lack of structural elements, such as litter, nests and perches to perform natural behaviours.

There is a strong movement to replace conventional cages by more spacious and structured furnished cages, barns, or aviaries with or without access to winter garden or free range.

Large groups and the behaviour of free moving hens in alternative systems represent particular challenges for the egg producers and poultry breeders.

Good nesting behaviour is required to reduce the number of floor eggs. Fear and sudden outbreaks of panic or nervousness in large groups in cage free systems not only lead to reduced performance but also increase mortality through suffocation of hens in corners in the litter area and nest.

Damages of feather pecking and cannibalism can be exacerbated in large groups as is the case in alternative systems.

Keywords: Laying hens, welfare, behavior, fear, smothering, feather pecking, nesting, dual purpose breeds, molt, in-ovo sexing

Further welfare problems in layer strains are molting of hens by using feed restriction and culling day-old male chicks of layer lines.

Conventional methods to molt layers based on withdrawal of feed, water and light have been phased out in many countries and are being replaced by non-fasting methods.

Moreover, molting may become obsolete thanks to selection for persistent egg production and stronger eggshell quality, which allows extended laying periods in practice.

There is a strong opposition in some countries against culling day-old male chicks of layer lines. Rearing the male chicks up to slaughter weight or using dual purpose breeds and sex determination in-ovo are being investigated and tested at present as alternatives.

INTRODUCTION

In the past the consumption of eggs as a valuable source of protein for human nutrition was the privilege of the wealthier part of the human population. The development of high producing genetic lines, intensive husbandry systems and use of balanced compound feed has led to a dramatic reduction of costs and market price for poultry eggs. At the beginning of intensive egg production in the 1950ies, the price for 6 eggs was the equivalent of an hourly wage rate. Today more than 150 eggs can be bought for a one-hour wage. Eggs, as an excellent protein source, have become affordable for all social groups in industrialized countries. The decrease in production costs is mainly based on genetic progress, prevention of diseases and keeping large populations under specialized housing systems. These developments have improved not only the productivity, liveability and efficiency of the birds; but also the eco-footprints, such as emission of greenhouse gases and ammonia, and improved the utilization of scarce raw materials, energy and water (Flachowsky, 1992; Dekker et al., 2012, Pelletier et al., 2014). The key parameter of the simultaneous

Figure 1. *While intensive cages became the prevailing egg production system the tradional free ranging chickens persists in the memory of the urban population.*

improvement of economic and environmental criteria is the change in feed efficiency. While more than 3 kg of feed was required to produce 1 kg of egg mass in the 1950ies (Roemer 1953), the feed : egg conversion ratio has decreased to less than 2 : 1 at present. Intensive keeping of farm animals and laying hens in particular, has been subject to reservation in industrial countries (Bessei 2018). Indeed, the caged laying hen has been used as a symbol of animal suffering (Dawkins, 1980).

The reasons for this response are manifold. One of the most important aspects was the rapid transition from the family flock in the unlimited free-range system to the intensive deep litter system and cages. This development occurred in Europe between the 1950ies and 1970ies and helped to improve the health status of the flocks and better control of the environment which had a positive effect on the productivity and liveability of the birds.

Furthermore, it allowed high automatization of egg production and reduced the workload for the farmers. The view of the traditional free-range system, however, persisted in the memory of the urban population and has been often idealized **(Figure 1)**.

Scientists, mainly in Northern European countries, expressed their concern about the extremely restricted space allowance and the lack of nests, perches and litter (Blokhuis et al., 2007).

Consequently, conventional cages were banned in the EU as of 2012. In some countries, like Switzerland, Finland and Sweden conventional cages were banned even before that time.

Resistance against caging of laying hens has emerged with some delay in North America and in Australia and attempts to introduce “cage-free” systems is gaining momentum continuously (Windhorst, 2016). In the USA, California formulated minimum requirements for laying hens in a way that bans conventional cages.

Other states established similar regulations (Vizzier-Thaxton et al., 2016). In the meantime, retailer and restaurant chains in the US and Canada announced a stop of eggs produced in conventional cages in favour of cage-free eggs in the short or medium term. It has been estimated that 50 percent of the eggs in these two countries will be produced in alternative systems, such as barns, aviaries and free range within the next five years.

With the transition from cages to cage-free systems, the hens can enjoy more freedom to move and express locomotor activity, scratching and dustbathing, nesting and perching behavior. With the relatively new non-cage systems new issues are arising, which must be considered carefully.

Management has to be adapted accordingly and birds must be reared in systems that are similar to the system that the birds will find in production.

Birds need to learn to fly and to move appropriately in the system to find water and feed. More labour and time is needed to monitor the bird behaviour and take appropriate actions if needed. From a breeding point of view, in addition to conventional selection criteria like egg production, feed conversion and egg quality, traits related to animal welfare have become more specific weight in the selection index in the last decade. Special testing performance under alternative systems have been developed to collect this information (Icken et al., 2012; 2013a).

Besides new regulations and new challenges related to housing systems, the egg industry is facing other critical arguments against common practices, such as the procedure of beak treatment, molting and culling of day-old male chicks of layer strains. In the following text we will present the state of knowledge on the above-mentioned welfare topics.

WELFARE PROBLEMS RELATED TO MANAGEMENT SYSTEMS

Obviously, birds in modern alternative systems benefit from more space, physical activity and the ability to express natural behaviour. However, in the non-cage systems laying hens are facing other problems, which compromise their welfare and need to be addressed by egg producers and layer breeders.

FEAR, NERVOUSNESS AND SMOTHERING

Nervousness and repeated episodes of vigorous flight reactions (hysteria) have been reported as a widespread problem if layers are kept in large colony cages or on slatted floor without litter. Hysteria is characterized by a sudden increase in vocalization (squawking), flying around and running (streaming) without obvious reason and attempts to hide in a corner or underneath the feeders and drinkers. Strain, large group size and high stocking density have been identified as influencing factors (Hansen, 1976). Hysteria caused reduced egg production, damages of the feathers and wounds from scratches. Hysteric episodes of smothering also lead to high mortality when the flock is piling up in a corner of the pen after a vigorous flight. Reducing group size and stocking density and the provision of structure elements, such as litter, perches and divisions of the space have been found to reduce the risk of outbreaks. Furthermore, music and to go through the flock with different colour clothes and at different hours so that the birds are getting used to new events and starting this already in the rearing can help to reduce nervousness.

Another type of smothering of hens may occur in connection with dustbathing and nesting. Chickens have a strong motivation for dustbathing when offered spacious littered areas.

Dustbathing is considered as natural behaviour which helps to keep the feather cover in good condition (Widowski and Duncan, 2000; Scholz et al., 2014). It is often observed that large numbers of hens gather in specific parts of the pen for synchronized dustbathing, particularly in the afternoon after oviposition. This can lead to overcrowding and smothering (Odén et al., 2002). Smothering can also occur in the context of oviposition. When searching for a suitable nest site, hens tend to crowd together in particular nest areas, mainly at the end of a nest line. Piling also occurs in connection with floor eggs, when hens lay eggs outside the nest in corners of the littered or slatted areas and attract the attention of group mates. Campbell et al. (2017) reported spontaneous smothering spread over the whole daytime and lasting from 1 minute to 6 hours. The authors observed a dynamic increase and shrinking of the aggregation. Neither the cause of aggregation nor that of the disintegration could be identified. There was no mortality in this case. In a survey on smothering in free-range flocks in the UK egg producers reported that more than 50 percent of their flocks were exhibiting this behaviour (Barret et al., 2014). Time and site of smothering, with exception of smothering in the nests, was unpredictable and highly variable. The mortality was generally low. Rayner et al. (2016) found that breed and nest box type as factors affect smothering in the nests. According to own experience smothering in the nests may lead to high mortality through suffocation and over-heating, especially under hot ambient temperature. Hence smothering is not only an economic but also a serious welfare problem in alternative layer systems. Division of nest rows in small segments and interruption of the perches in front of the nests reduce the risk of crowding in the nests. Further management recommendations to avoid or reduce the incidence of smothering are to generate distraction of the hens through acoustic enrichment, such as playing music or running the feeder chain in the afternoon. In addition, walking more frequently the birds, to avoid corners and spots with higher light intensity, temperature or different ventilation or scattering grain in the litter are reported as means to reduce the problem.

Fear has been assumed as influencing factor of the decision of hens to use or to avoid access to free range (Grigor et al., 1995). This has been confirmed in a study of Hartcher et al. (2016). The authors

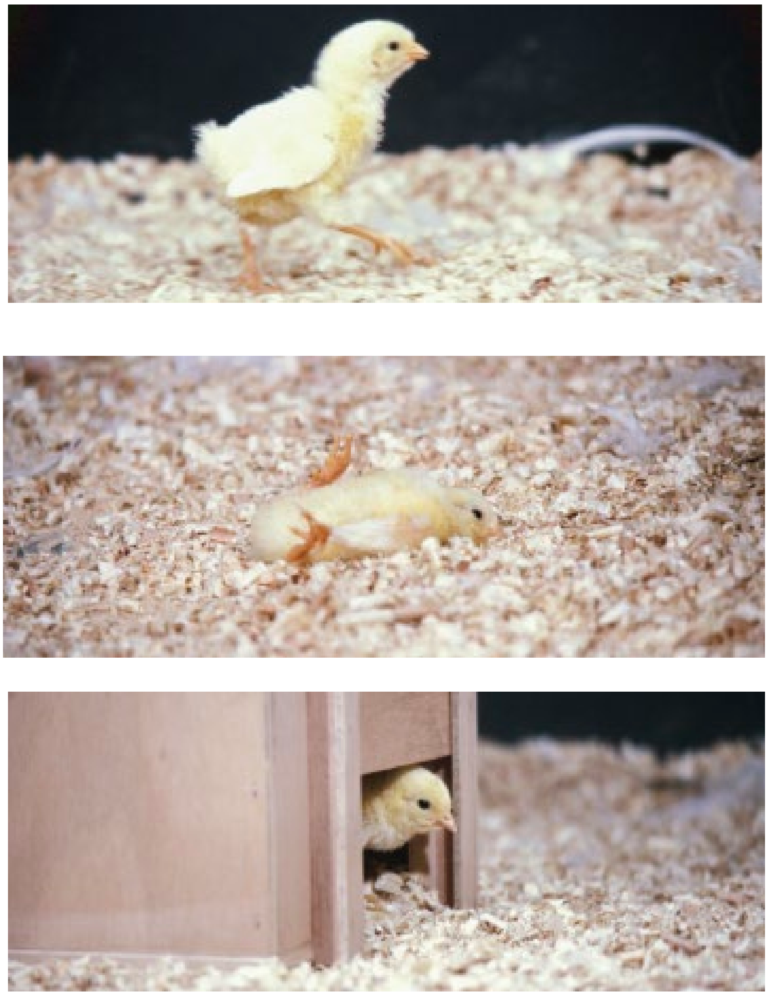

***Figure 2.** Open-field Test to measure fear in chickens(top): locomotor activity/exploration starts when fear vanishes, hence locomotor activity idicates low fear Tonic Immoblity test (Back- Test)(middle):Duration of immobility when chicks are turned on the back indicates high fear; Emerge-Test (bottom): Time to exit from a test-box after door opening indicates fear*

used RFID technology to analyse the use of free range in a layer flock. Hens, which made more visits and spent more time in the free range showed significantly less fear in a Tonic Immobility test.

It is generally assumed that panic and smothering is a form of fear response to environmental conditions. Fear in the domestic fowl has been shown to be heritable (Siegel, 1979).

There exist tests for fear, such as the Tonic Immobility Test (TI), Open-Field test (OF) and Emerge-Test, which can be easily performed in young chicks and included in the selection programs **(Figure 2**).

Further research is required to demonstrate the effectiveness of these procedures to reduce hysteria and smothering in commercial lines and crosses. Traditionally information from birds housed in family cages has been used to select for calmer birds that show less flightiness.

Future technologies that can automatically capture individual behaviour information in a group of birds in a cage-free environment could help to improve these traits.

However, an additional effort to adapt the environment and management to avoid these behaviours should be made

NESTING BEHAVIOUR

Nesting behaviour was not important as long as hens have been selected and kept in cages, especially for male lines. The female lines needed to have a good nesting behaviour for the parent stock performance already before the cage free era. With the transition from cage to alternative layer systems nesting behaviour of layer lines is gaining momentum. Eggs laid outside the nests are exposed to several challenges. They may become dirty and contaminated when laid in the litter, risk to break when laid on the slat or risk to be eaten. Minimizing floor eggs in commercial flocks requires special management procedures, such as early transfer of pullets to the layer facilities, frequent collection of floor eggs at the start of egg laying, avoiding of dark areas in the litter, facilitation of nest access, sufficient nest space, attractive nest lining. Even if all recommendations known to minimize floor eggs are followed, the problem cannot be solved by management procedures only. Primary poultry breeders have incorporated nesting behaviour and include suitable criteria in their composite selection index in order to adapt commercial strain crosses to non-cage systems. H&N and Lohmann Breeders have recognised this challenge and pedigreed breeding stocks are tested in floor systems in addition to the conventional performance test in cages for more than a decade. The development of the so-called funnel nest allows the identification of eggs of individual hens within flocks kept in pens **(Figure 3)**. The hens are tagged with a RFID tag, which identifies its entrance of the nest (Icken et al., 2012). The attribution of the eggs laid to the individual hen is enabled through special software. Egg production in the transponder nest system allows selection for nesting behaviour and contributes to reduce floor eggs in commercial flocks.

Figure 3. *The funnel nest allows identification of eggs laid by individual hens kept in groups. The hens are tagged with RFID tags at the legs. Special gates at the entrance prevent visits of more than one hen at the same time.*

FEATHER PECKING AND CANNIBALISM

Damage caused by feather pecking and cannibalism represents serious welfare problems not only in laying hens but also in growing turkeys, Muscovy ducks and other species of fowl. This behaviour can develop in pullets at young age and continue in adults.

Phases of intensive feather pecking usually precede cannibalistic pecking. The time of outbreak of feather pecking and cannibalism is unpredictable. Preferred areas of feather pecking are the lower back nearby the pygostyle, the vent and neck. In some cases, cannibalistic pecking at the toes and wing tips occurs without previous severe feather pecking.

Cloacal cannibalism or "peck-out" is often related to the eversion of the mucous membrane of the oviduct immediately at oviposition, in some cases as prolapse. Laying outside the nests, or bright light inside the nests make mucous membranes visible to the group mates and thus stimulates cloacal pecking.

Once a hen shows bloody spots on any part of the body, she becomes a target for being pursued and pecked by other hens. Thus, the wounded hens will be pecked to death within a few hours if not separated or treated with repellents.

The main cause of this behaviour is natural curiosity of hens using their eyesight and beak in search for edible feed. Many factors may contribute to the observed variation of incidence under commercial conditions. Nutrient deficiencies, lack of foraging materials, bright light, group size, stocking density and other risk factors have been identified (Nicol et al., 2013).

Recommendations to prevent this damaging behaviour comprise nutritional measures, such as increased levels of essential amino acids, minerals and crude fibre, and management procedures, such as providing hay baskets, pecking blocks or other occupation materials. The most efficient means are reduced light intensity and beak treatment (Flock et al., 2005).

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http://lohmann-information.com/content/l_i_48_artikel12.pdf

Beak treatment does not prevent feather pecking, but reduces damaged feathers, wounds from feather pulling and cannibalism as a result of bleeding wounds. Therefore, cannibalism rarely occurs in beak-treated flocks. Removal of the tip of the beak causes pain and has therefore been criticized by welfare organizations.

In some countries (e.g. Switzerland, Sweden, Norway, Finland) this treatment is generally prohibited. In the EU beak treatment as preventive measure against feather pecking and cannibalism is allowed in chicks up to 10 days of age when carried out by competent staff.

In some countries (e.g. Germany) beak treatment requires special allowance of the authorities in charge of animal welfare, and various countries announced a future ban of beak trimming. In order to anticipate legal measures against beak treatment

German egg producers decided to use intact-beak layers from 2017 onwards. It has been estimated that the use of intact-beak hens increases egg production costs, mainly through poor feathering and cannibalism (Damme and Urselmans, 2013).

To control damages in intact beak flocks a more intensive attention form the farmers is required in order to detect and react before this behaviour has been widespread in the flock. Based on a literature review Lambton et al. (2014) designed 46 bespoke management packages and tested them in a large-scale field study. Damages through injurious pecking could be reduced by adoption of the proposed management measures. But injurious pecking remained on a high level. The authors concluded that genetic selection should be used to control the problem.

Genetic variation of feather pecking has been found in various studies. Depending on the statistical model used the heritability varied between 0.11 and 0.20 (Bennewitz et al., 2014, Grams et al., 2014). Selection for high and low feather pecking or beak-inflicted injuries has proved to be effective in various selection experiments (Muir and Craig, 1998; Su et al., 2005).

While selection for high feather pecking has shown significant responses within a few generations the response was lower in the line selected for low feather pecking, and high feather pecking birds emerged in this line even after 11 generations of intensive selection (Piepho et al., 2017).

Commercial breeders however, do not have the tools to collect information on activity, fearfulness and measure feather pecking of individual birds within a group which are applicable in large numbers of breeding stocks and multiple lines at the same time. They rely on correlated traits which can be recorded more easily and with low labour input.

One of the strategies is keeping families in small groups and scoring the feather conditions as well as recording mortality. This procedure has proved to be effective and reduced damaging feather pecking to a low level. Additionally, since several years selection for a blunt beak has been incorporated in breeding programs to reduce the negative impact of feather pecking (Icken et al., 2017).

Regarding the multi-factorial nature of this behaviour, it was not possible to eliminate it with conventional genetic measures.

It is expected that the situation improves when markers for feather pecking are identified in the chicken genome. Research in this direction is currently carried out in different research institutes.

However, although some regions and different QTLs have been reported to have a significant effect on feather pecking, it seems to be a polygenic trait influenced by many genes with small effects (Iffland et al., 2020).

Using a combination of sensor technology and genomic methods to identify feather peckers and victims in groups could deliver a potential solution in the future (Ellen et al., 2019)

MOLT

The traditional method to molt layer flocks through withdrawal of feed, water and light for several days is prohibited in the EU. Chickens must have access to feed and water at any time (EU, 1999). In the USA, molting is not legally prohibited, but according to the welfare regulations of the largest egg producers association UEP fasting hens to introduce a laying pause is not permitted (UEP, 2016). Park et al. (2004) investigated alternatives to feed withdrawal in the USA. “Soft” methods of introducing a laying pause, such as using low-sodium diets (Bessei, 1978) or replacing the compound layer feed through grain only are applied in Germany for more than 30 years (Petersen and Goebel,1996).

Using these methods, the birds have access to feed and water. The light period is reduced to a minimum of 8 hours. Since breeding companies select lines continuously for longer laying persistency, molting layers may become obsolete. Nowadays hens can be kept for egg production for more than 90 weeks of age (Flock and Anderson, 2016). The focus is set not only on egg production but also in keeping a good eggshell quality, especially at advanced age. This combination allows extending the productive life of the birds and the total lifetime performance. Furthermore, the number of broken or cracked eggs is reduced with a positive effect on the profitability of the business and on the quality of the product for the consumers.

CULLING DAY-OLD MALES OF LAYER LINES

It is generally known that egg production and weight gain in chickens are negatively correlated. This was the reason for the development in the middle of the last century of lines which are specialized in egg or meat production. This specialization is the basis for the high efficiency laying or growth rate and feed efficiency in each production segment. Consequently, not only it is possible to produce high quality animal protein at consumer-friendly prices, but also to make an optimal use of resources (feed, energy and land) as well as to reduce residues and emissions to preserve the environment.

Pelletier et al. (2014) calculated that in the US per kilogram of eggs produced, the environmental footprint for 2010 is 65% lower in acidifying emissions, 71% lower in eutrophying emissions, 71% lower in greenhouse gas emissions, and 31% lower in cumulative energy demand compared with 1960.These authors stated that 28 to 43% of these reductions can be attributed to improved bird performance.

Due to the antagonism between laying rate and growth rate, males of layer lines show an extremely slow growth and poor feed conversion compared to modern broilers **(Figure 4)**. Hence, it is not economical to produce meat using egg-type male chicks. It is current practice to cull them in the hatchery at day-old and use them as feed for zoo animals, raptors and carnivores pet. This procedure is being criticized and has attracted the attention of public media

***Figure 4.** Growth and feed intake difference between a layer male, a dual-purpose male and a conventional broiler Ross 308 with broiler feed. (Adapted from Andersson, 2014; Icken et al., 2013b and Aviagen 2019)*

especially in Germany. According to the German law of animal protection it is not allowed to kill animals without a "sound reason". Economic aspects are obviously not accepted as "sound reason" in this case. France and Germany have announced the ban of culling day-old males from layer lines from end of 2021.Three different methods are being considered as solutions of the problem. The first and straightforward method would be to grow the males to slaughter age. However, the poor feed conversion leads to high production cost and consumer price and the odd conformation of breast and thighs is not generally accepted by consumers (Koenig et al., 2012). The second method to handle the problem is the use of dual-purpose breeds. These breeds have been selected with the aim of using hens for egg production and the males for meat production. They represent a compromise between egg production and growth rate. Males of these lines have a higher growth rate than males of conventional layer hybrid lines **(Figure 5)**, but neither are they competitive to commercial broilers, nor are their sisters competitive with females of specialized layer lines. Because of the extended duration of the growing period and the poor feed conversion rate the ecological footprints are inferior to specialized breeds (Damme et al., 2015). Gangnat et al. (2018) studied the willingness of consumers in Switzerland to pay more for meat and eggs from dual-purpose breeds. Using dual-purpose breeds was appreciated by the consumers as alternative to culling of chicks. The consumers were prepared to pay 13 % higher prices than the actual price for conventional chicken meat, but 34 % lower than for organic chickens. The willingness to pay for eggs from dual purpose hens was 29 % higher than the actual price for conventional eggs and 9% lower than for organic eggs. These results have been confirmed by a similar study in Germany (Reithmayer and Musshoff, 2019). Interestingly, the consumers expressed their preparedness to pay a considerably higher price for the meat of dual-purpose birds, provided that they are kept under free range conditions. In both studies the disposition to pay premium prices for the dual-purpose breeds was

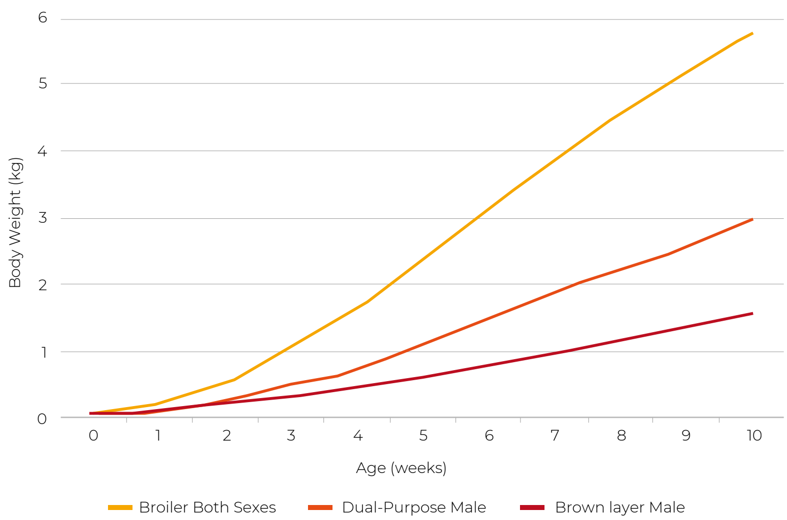

***Figure 5.** Growth and feed intake difference between a layer male, a dual-purpose male and a conventional broiler Ross 308 with broiler feed. (Adapted from Andersson, 2014; Icken et al., 2013b and Aviagen 2019)*

higher in consumers which usually buy organic products. It must be considered that both studies report the consumer's attitude, which may not reflect the final decision when buying. Despite the willingness of part of the consumers to pay a higher price, the dual-purpose breed always remains a compromise preventing the widespread use of this option.

The third option to avoid culling male chicks of layer lines is the identification of sex in the embryos either before or during incubation. Provided these methods are viable from the technical and economic point of view, the male eggs would not be incubated, or the male embryos would be destroyed in an early phase of development. According to Reithmayer and Musshoff (2019) German consumers generally accept in-ovo-sexing. This is in contrast with findings of Gremmen et al. (2018) in the Netherlands.

Krautwald-Junghanns et al. (2018) reviewed the different methods to identify the embryo`s sex in the early incubation phase: Determination of the hormonal level (estrone sulphate) in the allantoic fluid after nine days of incubation, optical and imaging methods, such as reflectance spectroscopy and hyperspectral imaging, infrared spectroscopy, Raman spectroscopy, magnetic resonance imaging, molecular sexing assays and genetic engineering. Various methods have shown promising results in the laboratory. The most important problem is to reduce the time needed to test large numbers of hatching eggs with high accuracy and low impact on hatching rate. Currently only two companies are already offering chicks from in-ovo sex determination on the European market (Preisinger, 2020). On the one hand, the company Seleggt (http://www.seleggt.de\) using the endocrinological approach (hormonal level in the allantoic fluid) after nine days of incubation. On the other hand, the company AAT (https://www.agriat.com/) using the optical approach. This last procedure for sorting embryos of brown layers on the 13th day of incubation has been already developed for a high throughput and it can be used immediately as a bridging technology in the hatcheries under commercial conditions (Preisinger, 2020). Other projects continue their investigations to implement in-ovo sexing determination at an earlier age under commercial hatcheries conditions. Using genetic engineering to mark the sex chromosome with a fluorescent protein would allow the determination of the sex even before incubation. General reservations against Genetically Modified Organisms (GMO) in European countries suggest that this method may not be accepted, even if all technical problems can be solved.

CONCLUSIONS

The transition from conventional cages towards alternative systems for laying hens in Europe and other industrialized countries is driven by welfare aspects. In the perception of the urban population non-cage systems are generally considered as animal friendly. These systems provide more freedom to move and a more variable and complex behaviour of the birds. The poultry keepers are facing particular problems related to the management of large groups, such as feather pecking and cannibalism, fear and smothering, nest utilization, use of perches and free-range areas. In order to recognize damaging or stereotyped behaviours in a flock on an early stage to minimize their negative effects, the birds need to be inspected frequently. Novel techniques, such as video-imaging may assist the observation of the flock. The traditional methods of molting layers using withdrawal of feed, water and light are not tolerated in European countries and in America any longer and need to be replaced by procedures which comply with the current welfare regulations.

The use of molt may become obsolete through the selection for extended laying periods. Culling day-old males of layer lines has become an important welfare issue. Alternatives to this problem are raising the male chicks to slaughter weight, using dual-purpose lines and in-ovo-sexing. All methods are considered to be ethically better than culling the day-old chicks. The use of these methods in commercial poultry production is being investigated at present. Two approaches for in-ovo sex determination by the companies Seleggt and ATT have successfully passed the field trials and are offering chicks sexed by these methods to the market. The end of the day-old male culling can only be achieved if all available alternatives are used, if more powerful technologies are available for the hatcheries and if capacities are gradually increased to a larger scale.

References:

Andersson, B. (2014, Data not published). Der Dual- und LB-Hahn im Vergleich zu einem extensiven Broiler. Bachelorarbeit – Hochschule Osnabrück, Osnabrück. Fakultät Agrarwissenschaften und Landschaftsarchitektur.

Aviagen (2019). Ross 308 Performance objectives 2019. Newbridge, Midlothian, Scotland, UK.

Barrett, J.; Rayner, A.C.; Gill, R.; Willings, T.H.; Bright. A. (2014): Smothering in UK free-range flocks. Part 1: incidence, location, timing and management. Vet Rec., 175: 19.

Bennewitz J., Bögelein S., Stratz P., Rodehutscord M.; Piepho H.P., Kjaer J.B., Bessei W. (2014): Genetic parameters for feather pecking and aggressive behavior in a large F2-cross of laying hens using generalized linear mixed models. Poult. Sci., 93: 810-817.

Bessei, W. (1978): Der Einfluß einer Na-armen Ration auf die Laufaktivität von Legehennen. In: Archiv f. Gefluegelkunde, 42: 246–248.

Bessei, W. (2018): Impact of animal welfare on worldwide poultry production. World's Poult. Sci. J., 74: 211-224.

Blokhuis, H. J.; van Fiks Niekerk, T.; Bessei, W.; Elson, A.; Guémené, D.; Kjaer, J. B. et al. (2007): The LayWel project. Welfare implications of changes in production systems for laying hens. World's Poult. Sci. J., 63: 101–114.

Campbell, D. L. M.; Lee, C.; Hinch, G. N.; Roberts, J. R. (2017): Egg production and egg quality in free-range laying hens housed at different outdoor stocking densities. Poult. Sci. 96:3128–3137.

Damme, K.; Urselmans, S. (2013): Infrared beak treatment – a temporary solution? Lohmann Information, 48: 36 -45.

Damme, K.; Urselmans, S.; Schmidt, E. (2015): Economics of Dual-Purpose Breeds. Lohmann Information, 49: 4 – 9.

Dawkins, M.S. (1980): Animal Suffering. The Science of Animal Welfare. Dordrecht: Springer Netherlands.

Dekker, S.; Groot Koerkamp, P. W. G.; Aarnink, A.; Boer, I. de (2012): Gaseous emissions from aviaries and nitrogen and phosphorus losses in the outdoor run of organic laying hens. ASABE - Int. Livest. Environ. Symp., ILES. ASABE - 9th International Livestock Environment Symposium 2012, ILES 2012.

Ellen, E.D.; van der Sluis, M.; Siegford, J.; Guzhva, O.; Toscano, M.J.; Bennewitz, J.; van der Zande, L.E.; van der Eijk, J.; de Haas, E.N.; Norton, T.; Piette, D.; Tetens, J.; de Klerk, B.; Visser, B.; Rodenburg, T.B. (2019): Review of Sensor Technologies in Animal Breeding: Phenotyping Behaviors of Laying Hens to Select Against Feather Pecking. Animals, 9: 108.

EU (1999): Richtlinie 1999/74/EG des Rates vom 19. Juli 1999 zur Festlegung von Mindestanforderungen zum Schutz von Legehennen. Amtsblatt der Europäischen Gemeinschaften L 203/53.

Flachowski, G. (1992): Nährstofföknomische, energetische und ökologische Aspekte bei der Erzeugung von eßbarem Protein tierischer Herkunft. Arch. Geflügelk. 56: 233.

Flock, D.K.; Laughlin, K.; Bentley J. (2005) Minimizing losses in poultry breeding and production: how breeding companies contribute to poultry welfare. World's Poult. Sci. J., 61: 227-237.

Flock, D.K.; Anderson, K.E. (2016): Molting of Laying Hens: test results from North Carolina and implications for US and German egg producers. Lohmann Information, 50: 12 – 17.

Gangnat, I. D. M.; Mueller, S.; Kreuzer, M.; Messikommer, R. E.; Siegrist, M.; Visschers, V. H. M. (2018): Swiss consumers' willingness to pay and attitudes regarding dual-purpose poultry and eggs. Poult. Sci., 97: 1089–1098.

Grams, V.; Bögelein, S.; Grashorn, M.A.; Bessei, W.; Bennewitz, J. (2014) Quantitative genetic analysis of traits related to fear and feather pecking in laying hens. Behav. Genet., 45: 228–235.

Gremmen, B.; Bruijnis, M.R.N.; Blok, V.; Stassen, E.N. (2018): A public survey on handling male chicks in the Dutch egg sector. J. Agric. Environ. Ethics, 31:93–107.

Grigor, P.N.; Hughes, B.O.; Appleby, M.C. (1995) Social inhibition of movement in domestic hens. Animal Behaviour, 49: 1381-1388.

Hansen R.S. (1976): Nervousness and Hysteria of mature female chickens. Poult. Sci., 55: 531 – 543.

Hartcher, K. M.; Hickey, K. A.; Hemsworth, P. H.; Cronin, G. M.; Wilkinson, S. J.; Singh, M. (2016): Relationships between range access as monitored by radio frequency identification technology, fearfulness, and plumage damage in free-range laying hens. Animal, 10: 847–853.

Icken, W.; Cavero, D.; Schmutz, M.; Preisinger, R. (2012): New phenotypes for new breeding goals in layers. World's Poult. Sci. J. 68: 387-399.

Icken, W., M. Schmutz, D. Cavero, R. Preisinger. (2013a) Dual purpose chickens: The breeder's answer to the culling of day-old male layers. Proc. IX European Symposium on Poultry Welfare, 17-20. June 2013 Uppsala, Sweden, p.91.

Icken, W.; Thurner, S.; Heinrich, A.; Kaiser, A.; Cavero, D.; Wendl, G. et al. (2013b): Higher precision level at individual laying performance tests in non-cage housing systems. Poult. Sci. 92: 2276–2282

Icken, W.; Cavero, D.; Schmutz, M. (2017) Selection on beak shape to reduce feather pecking in laying hens. Lohmann Information: 51: 22-27.

Iffland, H.; Wellmann, R.; Schmid, M.; Preuß, S.; Tetens, J.; Bessei, W.; Bennewitz, J. (2020) Genomewide mapping of selection signatures and genes for extreme feather pecking in two divergently selected laying hen lines. Animals: 10, 262.

Koenig, M.; Hahn, G.; Damme, K.; Schmutz, M. (2012): Untersuchungen zur Mastleistungund Schlachtkoerperzusammensetzung von Stubenkueken aus Masthybriden und verschiedenen Legehybridherkuenften. Zuechtungskunde, 84:511–522.

Krautwald-Junghanns, M-E; Cramer, K.; Fischer, B.; Förster, A.; Galli, R.; Kremer, F. et al. (2018): Current approaches to avoid the culling of day-old male chicks in the layer industry, with special reference to spectroscopic methods. Poult. Sci., 97: 749–757.

Lambton, S.L.; Knowles, T.G.; Yorke, C.; Nicol, C.J. (2015): The risk factors affecting the development of vent pecking and cannibalism in free-range and organic laying hens. Animal Welfare, 24: 101-111.

Muir, W.M.; Craig, J.V. (1998): Improving Animal Well-Being through Genetic Selection. Poult. Sci., 77: 1781–1788.

Nicol, C.J.; Bestman, M.; Gilani, A.M.; De Haas, E.N.; De Jong, I.C.; Lambton, S.; Wagenaar, J.P.; Weeks, C.A.; Rodenburg, T.B. (2013): The prevention and control of feather pecking. Application to commercial systems. World's Poult. Sci. J. 69 (4): 775–788.

Odén, K.; Keeling, L.J.; Algers, B. (2002): Behaviour of laying hens in two types of aviary systems on 25 commercial farms in Sweden. Brit. Poult. Sci., 43: 169–181.

Park, S.Y., Kim, W.K.; Birkhold, S.G.; Kubena, L.F.; Nisbet, D.J.; Ricke, S.C. (2004): Induced moulting issues and alternative dietary strategies for the egg industry in the United States. World's Poult. Sci. J., 60: 196-209.

Pelletier, N.; Ibarburu, M; Xin H. (2014): Comparison of the environmental footprint of the egg industry in the United States in 1960 and 2020. Poult. Sci., 93: 241-255.

Petersen, J.; Göbel, S. (1996): Wann lohnt sich eine induzierte Legeruhe? DGS Magazin, 14: 18- 21.

Piepho, H.-P; Lutz, V.; Kjaer, J. B.; Grashorn, M.; Bennewitz, J.; Bessei, W. (2017): The presence of extreme feather peckers in groups of laying hens. Animal 11: 500–506.

Preisinger R. (2020). Alternativen zum Kükentöten, Geschlechtsbestimmung im Brutei. Schweizer Geflügelzeitung 8/20:14-17.

Rayner, A.C; Gill, R.; Brass, D.; Willings, T.H.; Bright, A. (2016): Smothering in UK free-range flocks. Part 2: investigating correlations between disease, housing and management practices. Vet Rec., 179: 252.

Reithmayer, C.; Mußhoff, O. (2019): Consumer preferences for alternatives to chick culling in Germany. Poult Sci., 98: 4539- 4548.

Roemer, R.R. (1953): Nutzbringende Gefluegelwirtschaft. Verlag Eugen Ulmer, Stuttgart, Edition 3 – 5.

Scholz, B.; Kjaer, J. B.; Petow, S.; Schrader, L. (2014): Dustbathing in food particles does not remove feather lipids. Poult. Sci., 93: 1877–1882.

Siegel, P. B. (1979): Behaviour genetics in chickens: A review. World's Poult. Sci. J., 35:9-19.

Su, G.; Kjaer, J.B.; Sørensen, P. (2005): Variance components and selection response for feather-pecking behavior in laying hens. Poult Sci., 84:14- 21.

UEP (2016) United Egg Producers Animal Husbandry Guidelines

for U.S. Egg Laying Flocks 2016 Edition http://uepcertified.com/wp-content/uploads/2015/08/UEP-Animal-Welfare-Guidelines-20141.pdf, accessed August 2017.

Vizzier Thaxton, Y.; Christensen, K.D.; Mench, J.A.; Rumley, E.R.; Daugherty, C.; Feinberg, B.; Parker, M.; Siegel, P.; Scanes, C.G. (2016): Symposium: Animal welfare challenges for today and tomorrow. Poult. Sci. 95: 2198–2207.

Widowski, T.M.; Duncan, I.J.H. (2000): Working for a dustbath. Are hens increasing pleasure rather than reducing suffering?, Appl. Anim.Behav.Sci., 68: 39–53.

Windhorst, H.-W (2016): Cage-free heißt das Zauberwort. Ausstieg aus der Käfighaltung in den USA steht bevor. Deutsche Geflügelwirtschaft und Schweineproduktion 68: 1–5.

Improvement of welfare in BROILERS and TURKEYS

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SUMMARY

Concern about the welfare of broilers kept under intensive management systems is raised mainly in industrialized countries. Most welfare problems are related to early growth.

Fast growing broilers were susceptible to sudden death syndrome (SDS), Ascites and leg problems. Using slow growing breeds or reducing early growth would reduce these problems considerably. This strategy, however, would have a negative economic and environmental impact.

Genetic studies have shown that the mentioned problems can be solved when welfare aspects are considered in multi-trait breeding programs.

Progress in this respect has been demonstrated in commercial lines where the incidence of SDS, Ascites and leg problems was significantly reduced while growth rate was still improved.

Legislation of broiler welfare is focused on environmental factors, such as stocking density, enrichment and light. It has been shown that stocking density as such is not the primary cause of welfare problems.

However, high stocking density can lead to wet litter and increased heat and ammonia production. This results in decreased growth rate through heat stress and increased susceptibility to respiratory diseases, hock burns, and foot pad dermatitis. Stress parameters have not been found to be significantly influenced by increasing stocking density. Environmental enrichment is considered a useful tool to stimulate natural behaviour and to improve welfare in chickens.

Attempts to stimulate behavioural activities through enrichment showed only limited effects.

Perches as enrichment structure are used by a low percentage of the birds and may produce breast blisters.

Therefore, ramps and raised platform may be used instead of perches. The traditional lighting system with continuous light has negative effects on behavioural activity and leads to enlargement of the eyeballs.

Even growth rate is compromised under continuous light. Dark periods of 4 to 6 hours not only improve performance but also welfare criteria.

Light intensity has only a marginal influence on both, welfare and performance. Blue and green light stimulate growth rate.

The effect of light color on welfare criteria is not consistent throughout the experiments and needs further research.

Keywords: Broilers, welfare, performance, stocking density, litter, enrichment, light

INTRODUCTION

With the growth of the worldwide population, the demand for poultry meat as a valuable and cheap source of protein for human nutrition increases continuously. The expansion of poultry production is mainly based on intensive production systems, which include broiler breeds with high performance, compound feed and large populations kept under high stocking density. Intensive production of farm animals, and in particularly poultry, has been subject to criticism in industrial countries (Bessei, 2018). Only 3% of the population in industrial countries is living in rural areas while the share of the rural population in developing countries is 40 to 50% (Ribbekk, 2005). Urban societies are lacking knowledge on the present husbandry systems and the major part of the population has some idealistic views of animal production, which is far from reality. With increasing wealth of the population, especially in Northern European countries, animal welfare has gained momentum among consumers, government authorities as well as retailers. There exists a large number and variety of legal acts and directives concerning animal welfare. These regulations are mainly aiming at improving the environmental conditions. Nevertheless, welfare criteria are also considered in commercial animal breeding (FAIP, 1999; Neeteson et al., 2020). At a fixed point in time, the higher level of animal welfare leads to higher production costs, which are seldom balanced by higher productivity or price for the products (Schrader, 2013) -but over time welfare has improved simultaneously with production(Avendaño et al, 2017).

It is well documented, that most consumers, who express a positive attitude towards animal welfare, are not prepared to pay a higher price when buying poultry products.

Welfare problems on meat producing poultry were mainly related to rapid early growth. Broilers of the 1960ies needed about 56 days to reach 1 kg of live weight. At the same age, modern broilers grow to 4.2 kg (Zuidhof et al., 2014). Though intensive feeding and management contribute to the actual rapid growth, the largest effect can be attributed to genetic selection. The main welfare problems in broilers and turkeys were leg problems, failure of the cardiovascular system and reduced locomotor activity.

These problems are often intensified through intensive feeding and management procedures. It is the aim of the present study to review the present state of knowledge of the most important welfare related issues and the achievements to solve the problems.

ANIMAL - ORIENTED PROBLEMS

Skeleton

Damages of the leg skeleton and lameness represent a considerable part of mortality in broiler flocks. Tibial Dyschondroplasia (TD), deformation of tibial and femoral bones as well as degeneration of the femoral head are the generally known skeleton damages. TD can be identified in living birds using X-ray technology (Lixiscope). Using this technique, Ducro and Sørensen (1992) estimated the heritability of TD to be 0.33. The incidence of TD could be reduced by 50 percent within one selection generation. The Lixiscope technique has been efficiently used in commercial broiler breeding (McKay, 1997) and TD occurs only rarely in modern broiler strains.

Similarly, it was possible to significantly reduce the deformation of femur and tibia bones by genetic selection (Sørensen, 1992) and the leg conditions are now considered in commercial broiler and turkey breeding. There is generally a low negative correlation between leg bone conditions and growth rate (Rekaya et al., 2013). Using multi-trait selection programmes including TD, bone criteria and gait scores allows improvement in leg conditions with marginal effects on the selection progress in growth rate. This confirms the report of Kapell et al. (2012). Long term simultaneous selection against various leg abnormalities resulted in significant reduction of welfare –related criteria, such as leg bone deformities, crooked toes, hock burns and TD.

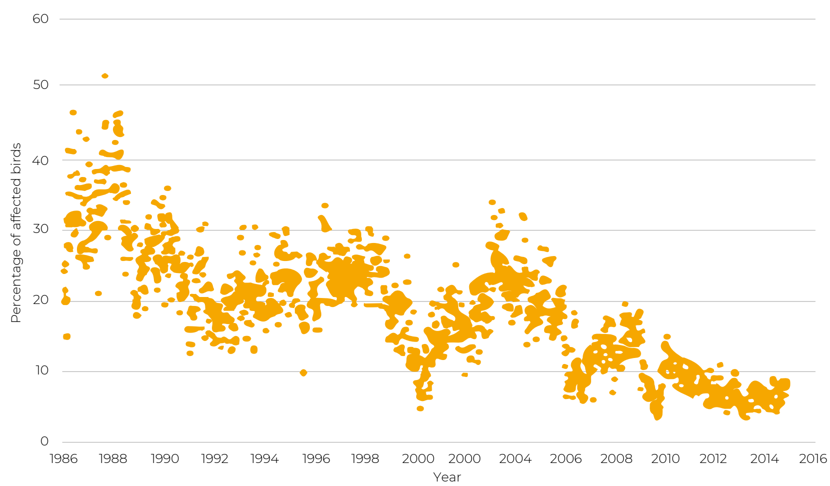

***Figure 1.** Response of leg defects in a commercial fast growing broiler strain after 26 years of selection (Neeteson et al, 2016).*

Figure 1 shows the decrease in leg defects in a fast growing broiler strain from about 30 to less than 10 percent.

Independent records of condemnation rates due to leg problems in Canadian poultry slaughter plants reflect the successful transfer of the selection response to commercial broiler production.

According to the Canadian Food Inspection Agency, leg condemnation rates per 10 000 birds have decreased significantly from 1995 onwards (Canadian Food Inspection Agency, 2020; figure 2). Varus valgus deformation was the criterion for condemnation from 1995 to 2007. From 2008 onwards, the statistics show all leg condemnations. This explains the small increase of the condemnations in the following years.

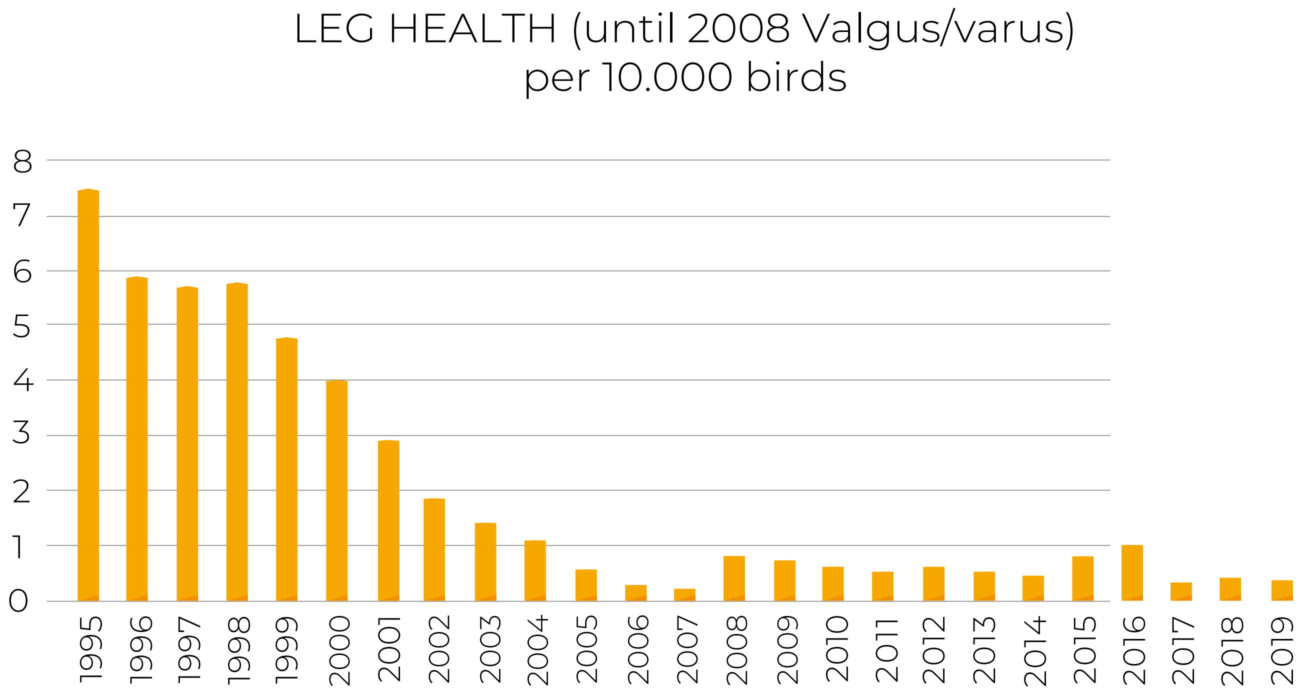

Figure 2. *The reduction of leg condemnation rates in broilers was particularly important in the 1990ies and reflect the improvement welfare conditions (Canadian Food Inspection Agency 2020).*

Dermatitis

Lesions at the footpads (footpad dermatitis; FPD) and hock burns can occur frequently in growing broilers and turkeys. They are the result of skin inflammation, which is spreading on the surface, and extend to deeper areas of the tissue.

There exist different scoring systems, which rank the size and severity of dermatitis. Hocking et al. (2008) proposed a scoring system for FPD in turkeys from 0 (no lesions) to 4 (large and deep lesions) **(table 1).**

Table 1. *Definitions of different scores of FPD in turkeys (Hocking, et al., 2008)*

Score	Description of foot pad
0	No external signs of FPD. The skin of the foot pad feels soft to the touch and no sweeling or necrosis is evident.
1	The pad feels harder and denser than a non affected foot. The central part of the pad is raised, reticulate scales are separated and small black necrotic areas may be present.
2	Marked sweelling of the food pad. Reticulate scales are black, forming scale shaped necrotic areas. The scales around the outside of the black areas my have turned white. The area of necrosis is less than one quarter of the total area of the foot pad
3	Swelling is evident and the total foot pad size is enlarged. Reticulate scales are pronounced, increased in number and separated from each other. The amount of necrosis extends to one half of the foot pad.
4	As score 3, but with more than half the foot pad covered by necrotic cells.

Lesion scores of >2 are considered to compromise the bird`s welfare seriously.

A special scoring system exists in Scandinavian countries. A total of 100 footpads of a flock is scored using three categories:

Score 0 : No or very small superficial lesions, slight discoloration on limited area of the foot pad, mild hyperkeratosis or healed skin

Score 1 : substantial discoloration of the foot pad, superficial lesions, dark papillae.

Score 2: ulcers or scrabs of significant size, signs of haemorrhages or severely swollen foot pads. The scores are adjusted to their severity by multiplying score 1 by 0.5, and score 2 by 2. The resulting sum represents the adjusted score. In Sweden score 40 is set as pass. Higher scores are being tolerated in other European countries.

The percentage of birds showing FPD varied between 0 and 100 (Kjaer et al., 2006). Wet litter is the most important causal factor for the development of FPD (Mayne et al., 2007; Youssef et al., 2011). Nevertheless, variation exists of the incidence of Dermatitis among genetic strains kept under similar environmental conditions, which indicate a genetic basis of the problem (Allain et al., 2009; Haslam et al., 2007).

Kjaer et al. (2006) estimated the heritability of FPD of 0.31 and for hock burns of 0.08. The genetic correlations between body weight and the different types of dermatitis were small and not significant.

The genetic correlations between FPD and body weight was low and showed positive as well as negative values. Low positive phenotypic correlations between both criteria have been reported in various studies (Bessei et al., 2012; da Costa et al., 2014).

Data suggest that genetic selection against FPD would not seriously impair progress in growth rate. It has been suggested that pain caused by FPD would compromise locomotor activity (Martland, 1984) and prevent the birds from accessing feeders and drinkers. Since FPD is mainly caused by wet litter, reduced body weight and high incidence of FPD may be the result of co-occurrence rather than of a causal relationship (Mayne et al., 2007).

Since breeding programs select against footpad dermatitis (Kapell et al, 2012b; Ralph, 2017), and producers implement footpad reduction strategies, footpad dermatitis has been much reduced in both broilers and turkeys.

From 2003 to 2013 the incidence of the adjusted score < 40 (Scandinavian system) in commercial broilers increased from 30 to 75 % and the worst category (score > 120) decreased from 15 to 3 % (Steenberg 2014).

Similar improvement in food pad scores in broilers have been reported in Finland from 2012 to 2019 (Animal Health ETT 2020; figure 3).

Each batch of broilers is scored by official meat inspection using the Scandinavian scoring system. Data shown in figure 3 represent > 90 % of total broilers slaughtered in Finland.

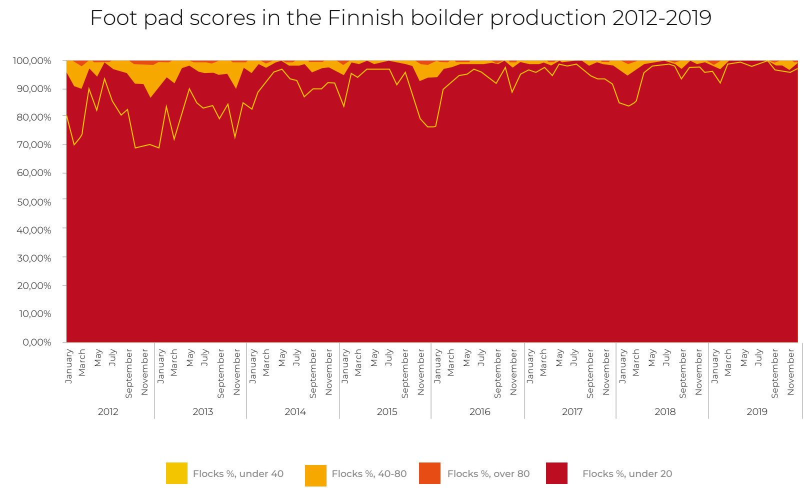

***Figure 3.** Change in foot pad scores in commercial broilers in Finland from 2012 to 2019 (by courtosy Dr. Hannele Nauholz, Veterinary Advisor, Animal Health ETT)*

Behaviour

The behaviour of fast growing broilers is characterized by reduced locomotor activity, increased resting (sitting and lying) and alteration of the gait. Chicks of broiler strains show lower activity than those of layer strains from the first week of age (Savory, 1975).

There is a sharp drop from the second week onwards (Reiter and Bessei, 1998). Besides the low level of general locomotor activity, an increasing number of birds were showing irregular gait pattern and lameness.

Under practical rearing conditions gait quality is usually scored using subjective criteria as described for broilers by Kestin et al. (1992) and Webster et al. (2008) **(table 2).**

***Table 2.** Five-point-gait scoring system (Kestin et al. 1992; Webster et al., 2008, slightly modified)*

Score	Description
0	No visible abnormality
1	Slight defect in walking ability; irregular gait
2	Clearly identifiable gait problems with no or little hindrance of movement
3	Obvious gait defect, with hindrance to move (limp, jerky and unsteady stride)
4	Sever gait defect. Capable of walking when driven or motivated by feed; sits down after a few steps
5	Unable to walk; shuffling on shanks or hocks with assistance of wings

Body weight, and in particular rapid growth rate during the first weeks of age, was assumed to be the most important reason for poor gait quality (Kestin et al. 2001; Djukic et al., 2004). The incidence of intermediate and severe gait problems was about 25 percent (Kittelsen et al., 2017) even though the broilers were kept under moderate stocking density and were slaughtered at the early age of 31 days. Kestin et al. (1992) reported similar percentage of broilers with gait problems.

Su und Sørensen (unpublished; loc. cit. Muir und Aggrey, 2003) estimated the heritability of gait scores of 0.20. Despite the obvious negative phenotypic effect of growth rate on gait score, the genetic correlation between these traits was small. Improvement of gait scores in broilers has been reported in Denmark. A compilation of data from 2001, 2005 and 2012 shows that gait scores 3 and 4 have disappeared and gait score 3 represents only 3 % **(Figure 4)**.

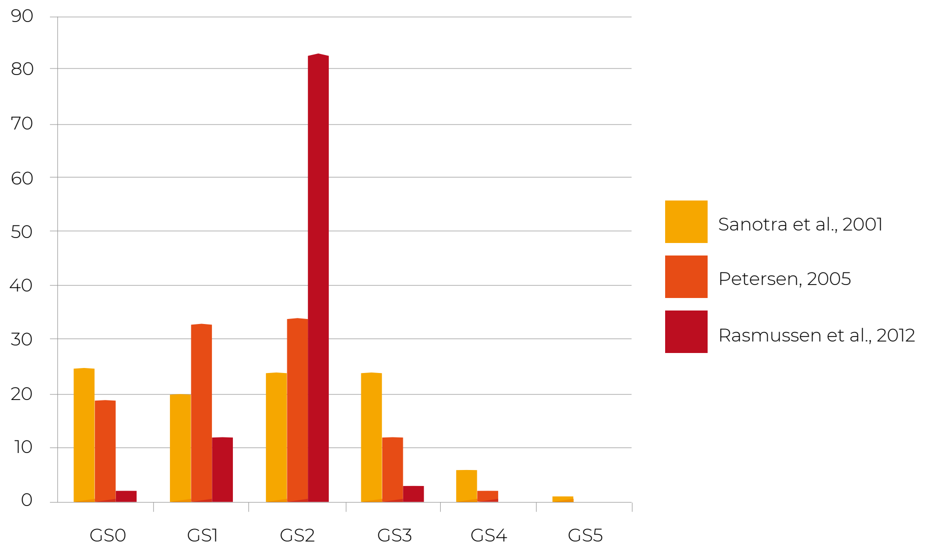

Figure 4. *Gait scores in Denmark reported in three papers: Sanotra et al., 2001; Petersen , 2005 and Rasmussen et al., 2012)*

In commercial turkey strains Swalander (2012) found genetic correlations between body weight (at 14 and 18 weeks of age) and gait score of 0.47 and 0.43, and between body weight and leg deformities of 0.47 and 0.45. The genetic correlation between gait score and leg deformities was much higher (0.85) than between gait score and TD (0.34).

This led to the conclusion, that TD does not necessarily produce leg deformities and impair gait in turkeys. TD should, however, be considered as risk factor, which may have an impact on gait and leg deformities in the presence of diseases.

SUDDEN DEATH SYNDROME (SDS) AND ASCITES

SDS and Ascites are the result of insufficient performance of the cardiovascular system (SDS: Gardiner et al., 1988; Grashorn, 1993; Maxwell and Robertson, 1997). Sudden death typically occurs in broilers, which do not show obvious symptoms of disease. The time span from the first signs of excitement and flip-over is from about half a minute to one minute (Newberry et al., 1987). Hence, the duration of suffering is short. Birds affected by Ascites, in contrast, suffer for several days and weeks before being culled or dying. Ascites is characterized by increase of the heart, change in liver function, insufficient performance of the lung (lack of oxygen) and accumulation of liquid in the abdominal cavern (Grashorn, 1993; Riddell, 1991). The common cause of both, SDS and Ascites is insufficient supply of oxygen of the fast growing muscles. Oxygen satiation of the blood is an indicator for the susceptibility of broilers for the diseases. In fact, genetic selection for high oxygen satiation in the blood has successfully reduced the incidence in modern broiler breeds (Avendaño et al., 2017; **(figure 5)**.

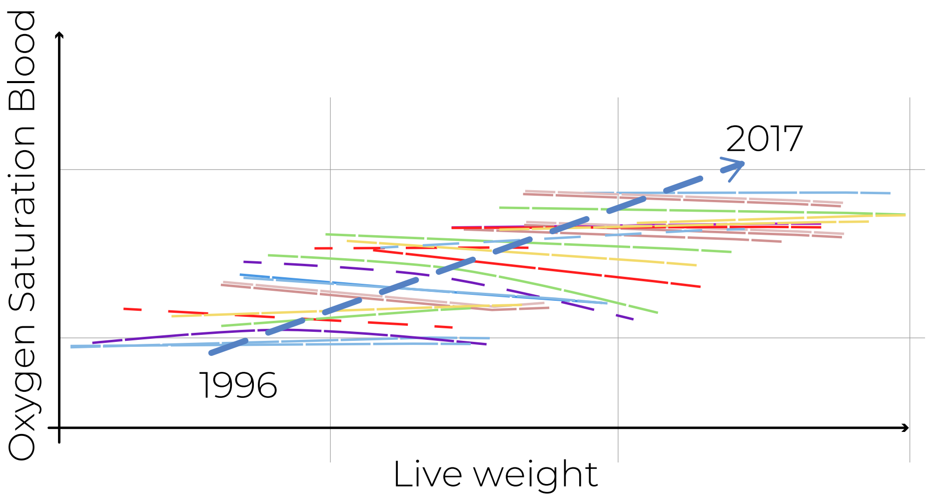

Figure 5. *Long-term relationship between body weight and oxygen saturation (Avendaño et al., 2017 2017). Each coloured line represents the relationship between breeding values within one year. The broken arrow represents the direction of the average breeding value.*

The response of selection for oxygen saturation is reflected in the report of the Canadian Food Inspection Agency on Ascites related condemnation rates (Neeteson et al, 2016; **(Figure 6)**.

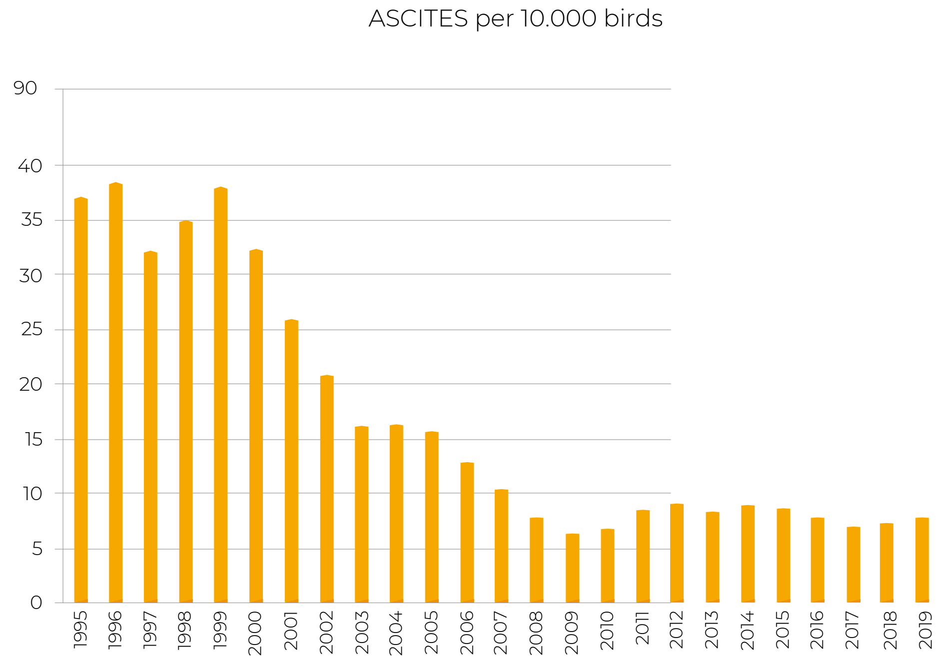

Figure 6. *Condemnation rates due to Ascites/Oedema recorded by the Canadian Food Inspection Agency from 1995 to 2019*

(http://www.agr.gc.ca/eng/industry-markets-and-trade/market-information-by-sector/poultry-and-eggs/poultry-and-egg-market-information/condemnations/?id=1384971854399#chicken)

ENVIRONMENTAL CRITERIA

Environmental criteria of broiler welfare are considered in EU directives and national laws in Europe and other industrialized countries. The scientific background of the most important welfare aspects, stocking density, litter, light and enrichment will be dealt with in the following.

STOCKING DENSITY AND LITTER CONDITION

Stocking density is the most prominent welfare criterion of broiler welfare. Since stocking density has an important influence on litter quality, both factors are closely related. According to the EU-directive on broiler welfare (EU, 2007) the basic stocking is 33 kg/m². This limit can be extended to 39 kg/m² when certain climatic factors, such as ammonia, CO2, temperature and humidity are kept within an optimum range. A further extension of stocking density to 42 kg/m² is permitted when in addition to the above mentioned criteria further improvement of the management is granted. Some European countries have introduced stricter rules on stocking density. In Germany, for example, stocking density should not exceed 39 kg/m² at any time.

For broilers up to 1600 g live weight an average stocking density of 35 kg/m² should not be exceeded in three consecutive crops. Welfare is also controlled at the slaughter plant. The cumulative daily mortality of each flock has to be reported, and if these data together with other criteria, such as Dead on Arrival (DoA), bruises, FPD, indicate poor welfare, the competent authority can impose lower stocking density for the next flocks.

Physical restriction of space has been considered as indicator of poor welfare in broilers under practical conditions. At the end of the growing period, the animals cover a major part of floor space. It has been assumed, that stocking density restricts locomotor behaviour and impairs access to feeders and drinkers.

Figure 7. *Low (20kg/m², top) and high stocking density (40 kg/m², down) of broilers at 5 weeks of age*

This assumption was supported by results showing that feed intake and weight gain decrease when stocking density exceeds 30 kg/m² (Shanawany, 1988; Grashorn and Kutritz, 1991; Wiedmer and Hadorn, 1998). Behavioural observations revealed that locomotor activity did not decrease when stocking density was increased from 30 to 40 kg/m² (Bessei, 1992).

Similarly, the increase of stocking density from 30 to 36 kg/m² did not significantly change lying behaviour (Bailie et al., 2018). However, there was a significant decrease of locomotor activity of stocking density in the range between 10 and 30 kg/m² (Blokhuis and van der Haar, 1990; Lewis and Hurnik, 1990; Reiter and Bessei, 2000). Body weight development is usually not impaired at this low level of stocking density. We can therefore not conclude, that impeded access to feed and water is the cause of reduced feed intake and growth rate under high stocking density. Reiter and Bessei (2000) found an increase in temperature at the litter surface higher than 30 centigrade, when stocking density increased to 40 kg/m². Since floor space is entirely covered by the animals at high density **(figure 7)**, ventilation amongst the birds is impaired and the heat produced by the animals and the microbial activity inside the litter cannot escape. Consequently litter temperature increased up to 31 °C **(figure 8).**

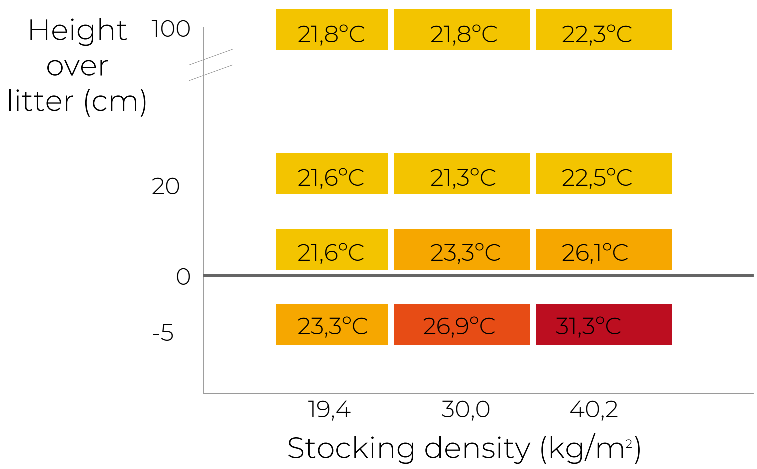

Figure 8. Temperature at different height above the litter and underneath the litter surface in response to stocking density (Reiter and Bessei, 2000)

It is well documented, that high temperature depresses the appetite and consequently the growth rate of birds. McLean et al. (2001) and Lolli et al. (2010) reported a rapid increase of panting with increased stocking density and litter temperature. Keeping broilers on perforated floor can attenuate the adverse effect of high temperature caused by high stocking density. The depression of growth rate occurred at higher stocking density when the birds are kept in cages (Andrews, 1972; Scholtyssek, 1973), on elastic perforated plastic floor (Scholtyssek and Grashorn, 1989), or on permeable tissue (Arkenau et al., 1997). However, keeping broilers and turkeys without litter is prohibited in European countries and deep litter systems prevail in commercial broiler production worldwide.

Buijs et al. (2009) recorded different criteria of broiler welfare in response to increasing stocking densities from 6 to 56 kg/m². There was no significant effect of stocking density on stress parameters such as the weight of bursa fabricii, corticosterone in the blood and mortality. Leg conditions were clearly affected by stocking density from 6 to 23 kg/m². Hock Burns increased when stocking density increased from 35 to 56 kg/m². Foot pad dermatitis at 56 kg/m² was significantly higher than at lower stocking densities.

Foot pad dermatitis is mainly caused by wet litter. Under practical conditions, many other factors influence the water content of the litter, such as ambient temperature, technique of water supply, diets, diseases and ventilation (Manning et al., 2007). The authors reported the correlation of 0.91 of water consumption per square meter and the incidence of food pad dermatitis and of 0.88 for water consumption per square meter and the incidence of condemnation rates of carcasses.

Wet litter is also an important source of ammonia in broiler houses. 10 ppm of ammonia caused damage of the lung of broilers and increased the susceptibility to respiratory diseases (Olanrejawu, 2008). Growth rate is affected by ammonia when the concentration exceeds 50 ppm. High ammonia contents of the litter aggravates the destructive effect of wet litter on footpad dermatitis. Algers and Svedberg (1989) found a direct relationship between the water and ammonia contents of the litter and footpad dermatitis. Stocking density from 10 to 35 kg/m² showed no influence on footpad dermatitis in this study.

The characteristics of the litter material, e.g. the capacity of water absorption and retention, and litter thickness play a vital role in this regard. The results of a meta-analysis on the effect of different types of litter on the incidence of FPD in turkeys are shown in table 3 (Bessei et al., 2012).

Cardboard and straw, whether dry or wet, produced the highest rates of FPD. Wet paper and wet wood shavings showed also high percentages of FPD. Wood shaving ranked better than straw under dry and wet conditions. The best results (3.7 %) were obtained with dry and clean wood shavings (table 3). This study did not include results of straw pellets, which are increasingly used in broiler and turkey production. Straw pellets have a high water absorption capacity and, when applied in small quantities, the litter remains dry and friable. This results in rates of FPD lower than 10% (own unpublished observations).

The incidence of FPD in turkeys and broilers is usually higher in winter than in summer (Ekstrand and Carpenter, 1998; Rudolf, 2008). This effect can attributed to poor litter conditions in the cold season. In order to reduce heat loss and to save energy, farmers tend to keep the ventilation rate on a low level. Suboptimal ventilation often results in wet litter and high incidence of FPD.

***Table 3** Percentage of Foot pad dermatitis in growing turkeys in response to litter substrate and dry matter (results of a meta-analysis) (Bessei et al., 2012)*

Sustrate	Humidity		Difference
	dry	wet	
Paper	33,9	88,8	54,9
Cardboard	83,7	87,2	3,5
Straw	81,9	85,9	4,0
Wood shav (clean)	3,7	52,3	48,6
Wood shav (conv.)	73,2	81,9	8,7

These results confirm the conclusion of Dawkins et al. (2004) that stocking density as such has no direct influence on welfare related criteria in broilers. It is the interaction of stocking density with other management factors, which influence performance and the well-being of the animals.

In this regard, litter condition is of utmost importance. The excretion of nitrogen, water and heat increase proportional with increasing stocking density. This leads to intensive microbial activity and increased temperature in the litter and increased ammonia in the litter and the air of broiler houses.

ENRICHMENT AND OCCUPATION

Conventional broiler growing is characterized by a barren environment. This is generally considered as cause of low variability of behaviour and low level of welfare. Enrichment devices should stimulate natural behaviours, such as scratching, dust bathing, exploration, and perching (Riber et al., 2018). Litter is usually accepted as occupation material. In many cases, however, litter is wet and caked and does not provide appropriate opportunity for pecking and dust bathing. Special welfare programs request additional materials of environmental enrichment. These materials should be attractive in order to stimulate desirable behaviours and to avoid undesirable behaviours (Jones, 2004). The material should also be workable in commercial farms, accepted by the birds and bear no health risks.

Supply of strings and special areas with dry sand has shown to increase the activity of broilers during the first weeks of life (Leterrier et al., 2001; Bailie et al., 2018). This effect however was numerically small and disappeared at the end of the growing period. Bailie and O`Connell (2015) reported even a negative effect of strings on the activity of broilers at the end of the fattening period. There was no clear effect of strings as occupation material on welfare related traits. Other materials, such as wood shavings, peat, oat shells and straw pellets are considered to increase behavioural activities. Peat and oat shells in particular have been found to be extremely attractive to stimulate dust-bathing behaviour (Baxter et al. 2018).

There was no effect of enrichment on leg conditions in this experiment. Mench et al. (2001) in contrast, found a significant improvement on the leg bones and on the behaviour of broilers when given the opportunity of scratching, climbing and perching.

Similarly, Kaukonen et al. (2017) could show that the gait quality was improved, when broilers were given the opportunity to use elevated platforms. In several other studies there were no or marginal effects of perches or ramps between feeders and drinkers on leg health and gait quality (Balog et al, 1997; Bizeray et al., 2001).Bench et al. (2017) found no effect of perches on performance, bone density and carcass quality of broilers. Theoretically, the use of perches could reduce the stocking density on the litter surface and relieve the birds from heat stress.

However, the use of perches decreases with increasing age and body weight. Hence, stocking density in the litter area is not significantly reduced at the end of the growing period when stocking density reaches its maximum.

Kaukonen et al. (2017) reported, that only a few birds perched under practical conditions. Rare use of perches have also been reported by other authors. Only 1% of the birds used perches when the birds were kept under low stocking density of 11 birds per square meter (Matrenchar et al., 2000).

The use of perches increased up to 10% when stocking density was increased to 20 birds per square meter. When the height of the perches was continuously adapted to the size of the birds, up to 22% of the birds used the perches (Davies and Weeks, 1995). The use of perches increased the incidence of breast blisters and breastbone deformation (Bokkers and Koene, 2003). To avoid breast blisters and breastbone deformation, it has been proposed to use ramps or raised platforms instead of perches.

Newberry and Shackleton (1997) tested the influence of vertical panels as structural elements in broiler pens. This form of enrichment is based on the observation that broilers prefer areas near walls for resting. Rodriguez-Aurrekoetxea et al. (2014; 2015) enriched large broiler pens with vertical panels and perches.

Panels lead to better use of the centre of the pens and thus, to a better dispersion of the birds over the total space. The panels had no influence on weight gain, behaviour, footpad dermatitis and fluctuating asymmetry as a stress parameter. Buijs et al. (2010) installed panels as separation elements in small broiler pens. The use of the area nearby the panels increased with increasing age and stocking density.

Birds resting in this area were less disturbed by pen mates than birds resting elsewhere. The use of vertical panels attached on the ceiling of commercial broiler houses is reported on **page 86** of this issue.

Variation in feeding programs has been considered as an opportunity for environmental enrichment in broilers. Ad libitum feeding of uniform pelleted feed is one of the causes of low behavioural activity. Attempts were made to increase the locomotor activity (walking, scratching and litter pecking) through variation of feed structure and feeding schedules. Scattering grain in the litter was not successful as long as pelleted feed was available in the feeder (Jordan et al., 2011).

Increase of activity could only be shown when the whole diet was distributed in the litter. Difficulty to increase the activity through feeding programs has also been reported by Pichova et al. (2016). There was no effect on the activity of broilers when feed was scattered in the litter. Only the distribution of highly preferred mealworms led to a short time increase of activity.

Another possibility to stimulate behaviour through feeding technique is sequential feeding. Two diets that differed in their contents of lysine have been presented in an alternating pattern (Bizeray et al., 2001). This feeding technique significantly increased litter pecking (foraging) and locomotor activity, but reduced growth rate. Reiter and Bessei (2009) increased the distance between feeders and drinkers from 2 to 12 m. This measure led to a more coordinated resting and activity behaviour among the birds, increase of locomotor activity and improved leg conditions. Growth rate was not significantly affected.

Riber et al. (2017) called attention to a general deficit of information on implementation and economical aspects of environmental enrichment in broilers under commercial conditions. To overcome this problem, a program to improve the welfare of broilers has been established in Germany since 2015 (Initiative Tierwohl, 2018). The program comprises reduced stocking density and enrichment devices. Progress of welfare is communicated to the consumer and the costs of enrichment are compensated through a special fund. At present about 400 000 broilers are produced under this scheme.

LIGHT

According to the EU directive as well as the German legislation on the welfare of broilers, houses have to be sufficiently illuminated. In windowless houses light intensity should be 20 lux in at least 80 % of the surface. A dark period of 6 hours minimum has to be provided.

Light programs

Broilers have traditionally been kept under a 23 hours light and 1 hour dark program. This represents quasi-continuous light conditions, which have shown optimum growth and feed conversion rates in former broiler lines (Morris, 1967). Extended dark periods showed positive effects on leg condition and mortality, but reduced weight gain, particularly in short growing periods (Zubair and Leeson, 1996).

Extended dark periods of 12 hours from 3 to 21 days of age, and continuous light thereafter, showed reduced body weight development compared to broilers kept under continuous light from day-old. Extending the growing period to 49 days compensated the shortfall (Thomsen, 1989). Bayram and Özkan (2010) found full compensation of reduced body weight development in response to an 8 hours dark period at 35 days of age. Dark periods of 16 hours could not be compensated at 56 days of age (Olanrewayu et al., 2018). Sørensen et al. (1999) reported reduced Tibial Dyschondroplasia in broilers kept under extended dark periods from 3 to 21 days of age. The positive effect of darkness has been attributed to the increase of locomotor activity during the light phase. Reiter and Bessei (2002) confirmed this effect: The intensity of locomotor activity during the light phase increased with increasing duration of the dark period. The phases of high locomotor activity during the light periods improved leg bone characteristics even though the total activity was not increased.

Continuous light not only reduces the locomotor activity but also prevents the development of circadian rhythm.

The expression of a circadian rhythm is considered as important indicator of animal wellbeing. Intermittent lighting programs with short light – dark phases, such as 2h light : 2h darkness, showed similar growth rate as continuous light (Onbasilar et al., 2007; Olanrewaju et al., 2018).

There is no circadian rhythm developed under these conditions.

Schwean-Lardner et al. (2012) found that a continuous dark period of at least 4 hours is required to enable the development of a circadian rhythm in modern broiler strains. In contrast to traditional broiler lines today's strains do not require continuous light or 23 hours light to show optimum weight gain and feed conversion rate.

According to their results the optimum dark period is between 4 and 8 hours **(Figure 9)**

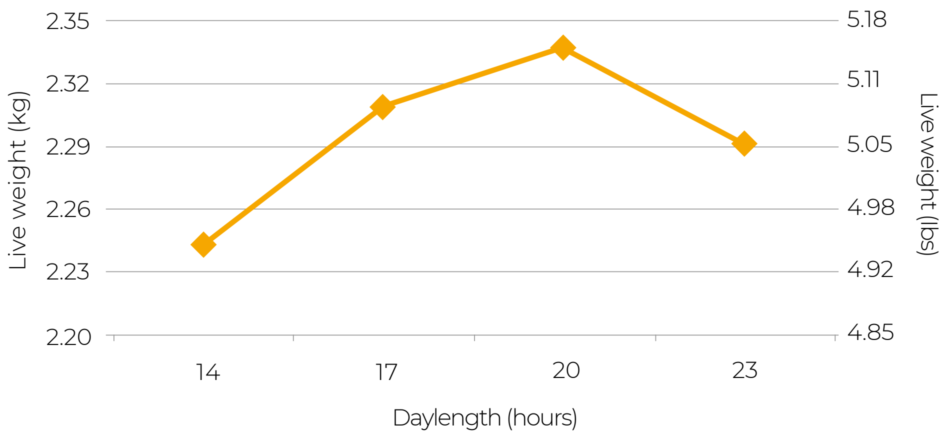

Figure 9. *Effect of daylength on live weight in broilers at 38/39 days of age (Graph produced on the basis of data of Schwean-Lardner et al., 2012)*

Continuous light leads also to an enlargement of the eyeballs of broilers (Lauber and McKinnear, 1979). The effect of this phenomenon on the bird`s welfare has not been studied so far. However, enlargement of eyeballs are considered as anatomical abnormality. Extension of the dark period to 4 hours prevented the increase of the eyeball in layer and broiler strains (Li et al., 2000; Schwean-Lardner et al., 2012).

Broilers experience hunger during extended dark periods. This leads to crowding and excitement in front of the feeders at the beginning of the light period. Stepping on the back of pen mates results in high incidence of deep scratches on the back skin. These injuries not only compromise the bird`s welfare but also lead to downgrading of carcasses at the processing plant. Under practical production conditions it is advised to limit continuous dark periods to 4 hours and provide a further dark period after a 1 to 2 hours light period, to match the legal requirement.

High activity of broilers kept under extended dark periods hampers catching procedures. In this regard continuous light should be introduced 2 to 3 days before slaughter. This procedure reduces excitement of the birds and is legally permitted.

Light intensity

According to the EU directive on broiler welfare light intensity at the height of the birds head should not be lower than 20 lux. Less than 10 lux is provided at the end of the growing period in many countries in windowless houses. There exists controversial information on the effect of light intensity on performance and leg conditions. Newberry et al. (1988) found positive effects of high light intensity (180 vs. 6 lux) on locomotor activity and leg health. In contrast, Gordon and Thorp (1994) reported higher deformation of the tibial bone under high versus low light intensity. Blatchford et al. (2009) compared body weight, behaviour, leg conditions and immune function of broilers kept under 5, 50 and 200 lux. Light intensity showed no influence on body weight, gait quality and immune criteria. The weight of the eyeball was higher at 5 lux than at higher light intensities. In all above-mentioned experiments, light intensity showed no effect on performance criteria. The incidence of discoloration of footpads and hock joints were highest at 200 lux, but more footpad erosion was found at 5 and 50 lux. Deep et al. (2013) reported a curvilinear response to increasing light intensity (0.1 to 10 lux) for feed intake, growth rate and mortality with optimum values at 5 lux. The incidence of footpad dermatitis decreased linearly with increasing light intensity. Gait quality was not affected.

Light quality

Studies on light intensity in chickens are problematic in so far as in most experiments light intensity is measured in lux, which is based on the sensitivity of the human eye for different wavelengths. In order to determine the perception of light intensity of chickens the conventional lux needs to be translated in chicken lux (clx) (Lewis and Morris, 1998). Using such translated values Kristensen et al. (2007) observed the behaviour of broilers kept under light intensities from 5 to 100 clx. There was no effect of light intensity on a wide range of behaviours. Only foraging was higher at lower light intensity.

Since the availability of LED lamps, which image defined spectra of light, information on the effect of light quality on chickens is gaining momentum. Rozenboim et al. (1999a;b) and Cao et al. (2008) found improved growth rates, when broilers where exposed to monochromatic blue and green light. The combination of blue and green light improved weight gain and carcass quality compared with incandescent white light (Rozenboim et al., 2004).

Information on the influence of light quality on welfare criteria is rare. Olanrevajo et al. (2015) raised broiler chicks under three different types of LED lamps and incandescent and fluorescent light as control. One LED type, which was quoted to be especially adapted to the sensitivity of the chicken ("cool poultry specific filtered LED") improved body weight gain compared to conventional incandescent lamps.

No significant differences were found among other light sources on other performance traits, weight of the eyeballs and plasma corticosterone. In a later study of Olanrevajo et al. (2018) the LED light adapted to the chicken eye improved body weight and carcass yield when compared with incandescent light. There was no significant response to the light sources on feed intake, feed conversion rate, mortality and immune response.

Rogers et al. (2015a,b) tested two different LED lamps with cold cathode fluorescent and conventional incandescent light as control. LED light showed similar results to the control concerning live weight, feed conversion rate and mortality.

Performance under cold cathode fluorescent light was lower than under incandescent and LED lights. There was no consistent trend of the Heterophile : Lymphocyte ratio as stress criterion in response to the light sources. The authors concluded that LED light had no negative effect on broiler welfare. Riber (2015) compared neutral-white LED (4100 K) and cold-white LED (6065 K) with regard to performance and behaviour. Birds raised on cold-white (6065 K) showed higher body weight at the end of the growing period (35 days).

There was a slight preference for this light source in choice tests. Behavioural observations revealed a tendency of more resting under 6065 K illumination. Both the increase of live weight and the preference for this light source was attributed to the higher proportion of blue light.

Positive influence of cold LED light (5000 K) with a higher proportion of blue/green colour versus warm LED light (2700 K) on weight gain and feed conversion rate have also been found by Archer (2017). In addition broilers kept under cold LED light showed less fear and less stress responses than those kept under warm light.

Blue light is generally considered to have a calming and fear reducing effect on chickens (Xie et al., 2008; Sultana et al., 2013). Reduced activity and increased growth rate may have detrimental effects on the leg conditions. Riber (2015), however, did not find such a negative effect on leg conditions (lameness and dermatitis) of 6065 K versus 4100 K.

This could have been due to the small effect of the light source on growth and activity. But it should also be considered that blue light exhibits its effect on growth during the later phase of the growing period, while leg problems develop in the first two weeks of age. Red and yellow light have been reported to increase the activity, aggression (Prayitno et al., 1997) and fear (Sultana et al., 2013) in chickens.

This may compromise welfare. However, these results need further investigations. Kaemmerling et al. (2018) compared the light spectra of the natural habitat of turkeys and chickens with commonly used artificial light sources including LED lamps.

The spectra of all artificial light sources deviated extremely from the light in the natural habitats.

In summary, blue and green light provided through monochromatic light or through white LED light with a higher proportion of green and blue, improve growth and feed conversion rate.

The effects of different types of LED light on behaviour and welfare criteria are lower and not consistent throughout the different studies. Further investigations are required in this respect.

References. *Algers, B., and J. Svedberg. 1989. Effects of atmospheric ammonia and litter status on broiler health, Proc. 3rd. Europ. Symp. on Poultry Welfare, Tours, France:237–241.*

Allain, V., L. Mirabito, C. Arnould, M. Colas, S. Le Bouquin, C. Lupo, and V. Michel. 2009. Skin lesions in broiler chickens measured at the slaughterhouse. Relationships between lesions and between their prevalence and rearing factors, Br. Poult. Sci. 50:407–417. doi: 10.1080/00071660903110901.

Andrews, L. D. 1972. Cage rearing of broilers, Poult. Sci. 51:1194–1197.

Animal Health ETT. 2020. Foot pad dermatitis, broiler – A suitable indicator for broiler flock welfare. https://www.ett.fi/wp-content/uploads/2020/03/Footpad-scores-Finland-2012-2019.pdf. Accessed April 2020.

Archer, G. S. 2017. Color temperature of light-emitting diode lighting matters for optimum growth and welfare of broiler chickens, Animal:1–7. doi: 10.1017/S1751731117002361.

Arkenau von, E. F., Macke, H. and Van den Weghe, H. (1997) Einfluss der Bodenbelüftung in Broilermastställen auf Tierleistung und Tierverluste. Züchtungskunde 69 :307-313.

Avendaño, S., Neeteson, A. and B. Fancher. 2017. Broiler Breeding for Sustainability and Welfare – are there Trade Offs? In: Proceedings Poultry Beyond 2023 Conference, New Zealand. 17pp. 2017. Broiler Breeding for Sustainability and Welfare – are there Trade Offs? In: Proceedings Poultry Beyond 2023 Conference, QUEENSTOWN, New Zealand,16 - 20 OC TOBER 2017New Zealand,:17pp.

Bailie, C. L. and N. E. O'Connell. 2015. The influence of providing perches and string on activity levels, fearfulness and leg health in commercial broiler chickens, Animal: an international journal of animal bioscience. 9:660–668. doi: 10.1017/S1751731114002821

Bailie, C. L., C. Ijichi, and N. E. O'Connell. 2018. Effects of stocking density and string provision on welfare-related measures in commercial broiler chickens in windowed houses, Poultry Science. 97:1503–1510. doi: 10.3382/ps/pey026.

Balog, J. M., G. R. Bayyari, N. C. rath, W. E. Huff, and N. B. Anthony. 1997. Effect of intermittent activity on broiler production parameters, Poult. Sci. 76:6.

Baxter, M., C. L. Bailie, and N. E. O'Connell. 2018. Evaluation of a dustbathing substrate and straw bales as environmental enrichments in commercial broiler housing, Appl. Anim. Behav. Sci. 20:78–85. doi: 10.1016/j.applanim.2017.11.010.

Bayram, A., and S. Ozkan. 2010. Effects of a 16-hour light, 8-hour dark lighting schedule on behavioral traits and performance in male broiler chickens, The Journal of Applied Poultry Research. 19:263–273. doi: 10.3382/japr.2009-00026.

Bench, C. J., M. A. Oryschak, D. R. Korver, and E. Beltranena. 2017. Behaviour, growth performance, foot pad quality, bone density, and carcass traits of broiler chickens reared with barrier perches and fed different dietary crude protein levels, Canadian Journal of Animal Science. 97:268–280. doi: 10.1139/cjas-2015-0202.

Bessei, W. 1992. Das Verhalten von Broilern unter intensiven Haltungsbedingungen, Arch. Gefluegelkde. 56:1–7.

Bessei, W. (2018): Impact of animal welfare on worldwide poultry production. In: World's Poult. Sci. J., S. 1–14. DOI: 10.1017/S0043933918000028.

Bessei, W., M. Rudolph and H.M. Hafez. 2012. The Incidence of Footpad Dermatitis in Experimental and Commercial Flocks from 1969 – 2011 A Historical Review, Proc. 9th International Turkey Symposium. Berlin, 21st – 23 June 2012.

Bizeray, D., C. Leterrier, P. Constantin, and J. M. Faure. 2001. Sequential feeding with low lysine diet induces higher level of activity in meat-type chickens, Proc. 6th Europ. Symp. Poultry Welfare, Zollikofen, Switzerland:173–176.

Blatchford, R. A., K. C. Klasing, H. L. Shivaprasad, P. S. Wakenell, G. S. Archer, and J. A. Mench. 2009. The effect of light intensity on the behavior, eye and leg health, and immune 7unction of broiler chickens, Pou. 88:20–28. doi: 10.3382/ps.2008-00177.

Blokhuis, H. J., van der Haar, J. W. 1990. The effect of the stocking density on the behaviour of broilers, Arch. f. Geflkde. 54:74–77.

Bokkers, E.A.M., and P. Koene. 2003. Behaviour of fast- and slow growing broilers to 12 weeks of age and *the physical consequences, App. An. Behav. Sci. 81:59–72. doi: 10.1016/S0168-1591(02)00251-4.*

Buijs, S., L. Keeling, S. Rettenbacher, E. van Poucke, and F. A. M. Tuyttens. 2009. Stocking density effects on broiler welfare. Identifying sensitive ranges for different indicators, Poult. Sci. 88:1536–1543. doi: 10.3382/ps.2009-00007.

Buijs, S., L. J. Keeling, C. Vangestel, J. Baert, J. Vangeyte, and F.A.M. Tuyttens. 2010. Resting or hiding? Why broiler chickens stay near walls and how density affects this, App. An. Behav. Sci. 124:97–103. doi: 10.1016/j.applanim.2010.02.007.

Canadian Food Inspection Agency. 2020. Condemnation Report 2019. http://www.agr.gc.ca/eng/industry-markets-and-trade/market-information-by-sector/poultry-and-eggs/poultry-and-egg-market-information/condemnations/?id=1384971854399#chicken

Cao, J., W. Liu, Z. Wang, D. Xie, L. Jia, and Y. Chen. 2008. Green and Blue Monochromatic Lights Promote Growth and Development of Broilers Via Stimulating Testosterone Secretion and Myofiber Growth, The Journal of Applied Poultry Research. 17:211–218. doi: 10.3382/japr.2007-00043.

Da Costa, M. J., J. L. Grimes, E. O. Oviedo-Rondón, I. Barasch, C. Evans, M. Dalmagro, and J. Nixon. 2014. Footpad dermatitis severity on turkey flocks and correlations with locomotion, litter conditions, and body weight at market age1, The Journal of Applied Poultry Research. 23:268–279. doi: 10.3382/japr.2013-00848.

Davies, H. C. and Weeks, C. A. (1995) Effects of age and leg weakness on perching behaviour of broilers. Brit. Poult. Sci. 36 :838

Dawkins, M. S., S. Donelly, and T. A. Jones. 2004. Chicken welfare is influenced more by housing conditions than by stocking density, Nature. 427:342.

Deep, A., C. Raginski, K. Schwean-Lardner, B. I. Fancher, and H. L. Classen. 2013. Minimum light intensity threshold to prevent negative effects on broiler production and welfare, Br.Poult.Sci. 54:686–694. doi: 10.1080/00071668.2013.847526.

Djukic, M., A. Harlander-Matauschek, and W. Bessei. 2004. The effect of weight load on the legs on locomotor activity and resting behaviour of fast and slow growing chickens, Proc. : 38th International Congress of the ISAE, Helsinki, Finland:183.

Ducro, B.J. and P. Soerensen. 1992. Evaluation of a selection experiment on tibial dyschondroplasia in broierl chickens. Proc. XIX World`s Poultry Congress, Amsterdam, 386 – 389.

Ekstrand, C. and T.E. Carpenter. 1998. Temporal aspects of of foot pad dermatitis in Swedish broilers. Acta Vet. Scand. 39: 273-280.

EU 2007. Council Directive 2007/43/EC Minimum rules for the protection of chickens kept for meat production.

Gardiner, E. E., Hunt, J. R. and Newberry, R. C. (1988) Relationship between age, body weight and season of the year and the incidence of sudden death syndrome in male broiler chickens. Poult. Sci. 67:1243-1249.

Gordon, S. H., and B. H. Thorp. 1994. Effect of light intensity on broiler liveweight and tibia plateau angle, Proc. 9th Europ. Poultry Conference, Glasgow, UK:286–287.

Grashorn, M. 1993. Untersuchungen zur Ätiologie und Pathogenese des plötzlichen Herztods bei Masthühnern, Hohenheimer Arbeiten, Verlag Eugen Ulmer, Stuttgart:123 S.

Grashorn, M., and B. Kutritz. 1991. Der Einfluß der Besatzdichte auf die Leistung moderner Broilerherkünfte, Arch. Geflügelk. 55:84–90.

Haslam, S. M., T. G. Knowles, S. N. Brown, L. J. Wilkins, S. C. Kestin, P. D. Warriss, and C. J. Nicol. 2007. Factors affecting the prevalence of foot pad dermatitis, hock burn and breast burn in broiler chicken, British Poultry Science. 48:264–275. doi: 10.1080/00071660701371341.

Hocking, P. M., R. K. Mayne, R. W. Else, N. A. FRENCH, and J. GATCLIFFE. 2008. Standard European footpad dermatitis scoring system for use in turkey processing plants, World's Poult.Sci.J. 64:323–328. doi: 10.1017/S0043933908000068.

Jones, R.B. 2004. Environmental enrichment: the need for practical strategies to improve poultry welfare. In: Welfare of the Laying Hen, pp. 215-225. G. Perry CAB International Wallingford, UK.

Initiative Tierwohl. 2018. https://initiative-tierwohl.de/impressum/

Jordan, D., I. Štuhec, and W. Bessei. 2011. Effect of whole wheat and feed pellets distribution in the litter on broilers' activity and performance, Arch.Gefluegelkunde. 75:98–103.

Kaemmerling, D., S. Döhring, A. Uhlenkamp and R. Andersson 2018. Lighting of Poultry Houses to Meet the Needs of Bird Eyes. Lohmann Information 51 (2), 24 – 34.

Kapell, D.N.R.G., W. G. Hill, A.-M. Neeteson, J. McAdam, A.N.M. Koerhuis, and S. Avendaño. 2012. Twenty-five years of selection for improved leg health in purebred broiler lines and underlying genetic parameters, Poult. Sci. 91:3032–3043. doi: 10.3382/ps.2012-02460.

Kapell D.N.R.G., Hill W.G., Neeteson A.M., McAdam J., Koerhuis A.N.M. and Avendaño S. 2012. Genetic parameters of foot-pad dermatitis and body weight in purebred broiler lines in 2 contrasting environments. Poultry Science 91:565–574.

Kaukonen, E., M. Norring, and A. Valros. 2017. Perches and elevated platforms in commercial broiler farms: use and effect on walking ability, incidence of tibial dyschondroplasia and bone mineral content, Animal. 11:864–871. doi: 10.1017/S1751731116002160.

Kestin, S. C., S. Gordon, G. Su, and P. Sørensen. 2001. Relationships in broiler chickens between lameness, liveweight, growth rate and age, Vet. Rec. 148:195–197. doi: 10.1136/vr.148.7.195.

Kestin, S., T. Knowles, A. Tinch, and N. Gregory. 1992. Prevalence of leg weakness in broiler chickens and its relationship with genotype, Vet. Rec. 131:190–194. doi: 10.1136/vr.131.9.190.

Kittelsen, K. E., B. David, R. O. Moe, H. D. Poulsen, J. F. Young, and E. G. Granquist. 2017. Associations among gait score, production data, abattoir registrations, and postmortem tibia measurements in broiler chickens, Poultry Science. 96:1033–1040. doi: 10.3382/ps/pew433.

Kjaer, J. B., G. Su, B. L. Nielsen, and P. Sørensen. 2006. Foot pad dermatitis and hock burn in broiler chickens and degree of inheritance, Poult. Sci. 85:1342–1348.

Kristensen, H. H., N. B. Prescott, G. C. Perry, J. Ladewig, A. K. Ersbøll, K. C. Overvad, and C. M. Wathes. 2007. The behaviour of broiler chickens in different light sources and illuminances, Appl. Anim. Behav. Sci. 103:75–89. doi: 10.1016/j.applanim.2006.04.017.

Lauber, J. K., and A. Kinnear. 1979. Eye enlargement in birds induced by dim light, Can. J. Ophthalm. 14:265–269.

Leterrier, C., C. Arnould, D. Bizeray, P. Constantin, and J. M. Faure. 2001. Environmental enrichment and leg problems in broiler chickens, Br.Poult.Sci. 42:S13-S14.

Leterrier, C., C. Arnould, D. Bizeray, P. Constantin, and J. M. Faure. 2001. Environmental enrichment and leg problems in broiler chickens, Br.Poult.Sci. 42:S13-S14.

Lewis, N. J., and J. F. Hurnik. 1990. Lokomotion of Broiler Chickens in Floor Pens, Pou. 69:1087–1093.

Lewis, P. D., and T. R. Morris. 1998. Responses of domestic poultry to various light sources, World's Poult.Sci.J. 54:21–25.

Li, T., H. C. Howland, and D. Troilo. 2000. Diurnal illumination patterns affect the development of the chicks eye, Vision Res. 40:2387–2393.

Lolli, S., W. Bessei, A. Cahaner, L. Yadgari, and V. Ferrante. 2010. The influence of stocking density on the behaviour of featherless and normally-feathered broilers under hot ambient temperature, Arch. Geflugelkunde. 74:73–80.

Manning, L., S. A. Chadd, and R. N. Baines. 2007. Water consumption in broiler chicken. A welfare indicator. World's Poult. Sci. J. 63:63–71. doi: 10.1079/WPS2006127.

Martland, M. F. 1984. Wet litter as a cause of plantar pododermatitis leading to foot ulceration and ameness in fattening turkeys, Avian Pathol. 14:241–252.

Martrenchar, A., D. Huonnic, J. P. Cotte, E. Boilletot, and J. P. Morisse. 2000. Influence of stocking density, artificial *dusk and group size on the perching behaviour of broilers. Br. Poult. Sci. 41:125–130. doi: 10.1080/713654921.*

Maxwell, M. H., and G. W. Robertson. 1997. World Broiler Ascietes survey 1996, Poultry International. 36:16–30.

Mayne, R. K., R. W. Else, and P. M. Hocking. 2007. High litter moisture alone is sufficient to cause footpad dermatitis in growing turkeys, British Poultry Science. 48:538–545. doi: 10.1080/00071660701573045.

McKay, J. 1997. The next decade - a breeders perspective, International Poultry Production. 5:9–11.

McLean JA, Savory CJ and Sparks NHC. 2001. Welfare of male and female broiler chickens in relation to stocking density, as indicated by performance, health and behaviour, Animal Welfare. 11:55–73.

Mench, J.A., J. P. Garner, and C. Falcone. 2001. Behavioral activity and its effects on leg problems in broiler chickens, Proc. 6th Eur. Symp. Poult. Welf. H. Oester and C. Wyss, ed. World's Poultry Science Association, Zollikofen, Switzerland:152–156.

Morris, T. R. 1967. Light requirement of the fowl, In: Carter, T. C. Environmental control in poultry production, Edinburgh-London.

Neeteson A.-M., Swalander, M., Ralph, J. and A. Koerhuis. 2016. Decades of Welfare and Sustainability Selection at Aviagen Chickens and Turkeys. AviagenBrief, July 2016.

Neeteson, A.-M., Avendaño, S. and Koerhuis, A. 2020. Chapter 6 in: The Economics of Farm Animal Welfare: Theory, Evidence and Policy (eds B. Vosough Ahmadi et al.) CABI Publishing, Walllingford (in press).

Newberry, R. C., and D. M. Shackleton. 1997. Use of visual cover by domestic fowl. A venetian blind effect?, Animal Behaviour. 54:387–395. doi: 10.1006/anbe.1996.0421.

Newberry, R. C., E. E. Gardiner, and J. R. Hunt. 1987. Behavior of chickens prior to death from sudden death syndrome, Poult. Sci. 66:1446–1450. doi: 10.3382/ps.0661446.

Newberry, R. C., J. R. Hunt, and E. E. Gardiner. 1988. Influence of light intensity on behavior and performance of broiler chickens, Pou. 67:1020–1025. doi: 10.3382/ps.0671020.

Olanrewaju, H. A., W. W. Miller, W. R. Maslin, S. D. Collier, J. L. Purswell, and S. L. Branton. 2018. Influence of light sources and photoperiod on growth performance, carcass characteristics, and health indices of broilers grown to heavy weights, Poult. Sci. 97:1109–1116. doi: 10.3382/ps/pex426.

Olanrewaju, H. A., J. L. Purswell, W. R. Maslin, S. D. Collier, and S. L. Branton. 2015. Effects of color temperatures (kelvin) of LED bulbs on growth performance, carcass characteristics, and ocular development indices of broilers grown to heavy weights, Poult. Sci. 94:338–344. doi: 10.3382/ps/peu082.

Olanrewaju, H. A., J. P. Thaxton, W. A. Dozier III, J. Purswell, S. D. Collier, and S. L. Branton. 2008. Interactive effects of ammonia and light intensity on hematochemical variables in broiler chickens, Poult. Sci. 87:1407–1414. doi: 10.3382/ps.2007-00486.

Onbaşilar, E. E., H. Erol, Z. Cantekin, and Ü. Kaya. 2007. Influence of intermittent lighting on broiler performance, incidence of tibial dyschondroplasia, tonic immobility, some blood parameters and antibody production, Asian-Aus. J.Anim.Sci. 20:550–555. doi: 10.5713/ajas.2007.550.

Petersen, J. Dansk Slagtefjerkræ (2005). Færre slagtekyllinger med benproblemer. Nyhedsbrevet danskkyling.dk. September. 13653. 4pp.

Pichova, K., J. Nordgreen, C. Leterrier, L. Kostal, and R. O. Moe. 2016. The effects of food-related environmental complexity on litter directed behaviour, fear and exploration of novel stimuli in young broiler chickens, Appl.Anim.Behav.Sci. 174:83–89. doi: 10.1016/j.applanim.2015.11.007.

Prayitno, D. S., C. J. Phillips, and D. K. Stokes. 1997. The effects of color and intensity of light on behavior and leg disorders in broiler chickens, Poult. Sci. 76:1674–1681. doi: 10.1093/ps/76.12.1674.

Ralph, J. 2017. Reducing Footpad Dermatitis in Turkeys. International Turkey Disease Symposium. Berlin. https://www.dropbox.com/s/b47kdiihfzua1ul/Ralph17Reducing%20Footpad%20Dermatitis%20

John%20Ralph%20Abstract%20Int%20Turkey%20Diseases%20Symp%20Berlin.pdf?dl=0

Rasmussen, I.K., Spangberg, A. and Kristensen, H.H. (2012) Screening af slagtekyllingers gangegenskaber anno 2011. Videncentret for Landbrug. Fjerkrae. Arhus Denmark. 11pp.

Reiter, K., and W. Bessei. 1998. Effect of locomotor activity on bone development and leg disorders in broilers, Arch. Geflügelk. 62:247–253.

Reiter, K., and W. Bessei. 2000. Einfluß der Besatzdichte bei Broilern auf die Temperatur in der Einstreu und zwischen den Tieren, Arch. f. Geflügelk. 64:1–3.

Reiter, K., and W. Bessei. 2009. Effect of locomotor activity on leg disorder in fattening chicken, Berl.Münch.Tierärztl.Wochenschr. 122:264–270. doi: 10.2376/0005-9366-122-264.

Reiter, K., and Bessei W. 2002. Biological rhythms of behaviour, 11th Europ. Poultry Conference, Bremen, Germany: 40.

Rekaya, R., R. L. Sapp, T. Wing, and S. E. Aggrey. 2013. Genetic evaluation for growth, body composition, feed efficiency, and leg soundness, Poult. Sci. 92:923–929. doi: 10.3382/ps.2012-02649.

Ribbekk, E. 2005. World Urbanization Prospects: The 2005 Revision United Nations Department of Economic and Social Affairs / Population Division, »www.un.org/esa/«.

Riber, A. B. 2015. Effects of color of light on preferences, performance, and welfare in broilers, Poult. Sci. 94:1767–1775. doi: 10.3382/ps/pev174.

Riber, A. B., H. A. van de Weerd, I. C. de Jong, and S. Steenfeldt. 2018. Review of environmental enrichment for broiler chickens, Poult. Sci. 97:378–396. doi: 10.3382/ps/pex344.

Riddel, C. 1991. Ascites and right ventricular failure in broiler chickens and ducks. In: Diseases of Poultry, 9th Edition Iowa State University Press: 839

Rodriguez-Aurrekoetxea, A., E. H. Leone, and I. Estevez. 2014. Environmental complexity and use of space in slow growing free range chickens, App. An. Behav. Sci. 161:86–94. doi: 10.1016/j.applanim.2014.09.014.

Rodriguez-Aurrekoetxea, A., E. H. Leone, and I. Estevez. 2015. Effects of panels and perches on the behaviour of commercial slow-growing free-range meat chickens, App. An. Behav. Sci. 165:103–111. doi: 10.1016/j.applanim.2015.02.004.

Rogers, A. G., E. M. Pritchett, R. L. Alphin, E. M. Brannick, and E. R. Benson. 2015a. I. Evaluation of the impact of alternative light technology on male broiler chicken growth, feed conversion, and allometric characteristics, Poult. Sci. 94:408–414. doi: 10.3382/ps/peu045.

Rogers, A. G., E. M. Pritchett, R. L. Alphin, E. M. Brannick, and E. R. Benson. 2015b. II. Evaluation of the impact of alternative light technology on male broiler chicken stress, Poult. Sci. 94:331–337. doi: 10.3382/ps/peu046.

Rozenboim, I., I. Biran, Z. Uni, B. Robinzon, and O. Halevy. 1999a. The effect of monochromatic light on broiler growth and development, Poult. Sci. 78:135–138. doi: 10.1093/ps/78.1.135.

Rozenboim, I., B. Robinzon, and A. Rosenstrauch. 1999b. Effect of light source and regimen on growing broilers, British Poultry Science. 40:452–457. doi: 10.1080/00071669987197

Rozenboim, I., I. Biran, Y. Chaiseha, S. Yahav, A. Rosenstrauch, D. Sklan, and O. Halevy. 2004. The effect of a green and blue monochromatic light combination on broiler growth and development, Poult. Sci. 83:842–845. doi: 10.1093/ps/83.5.842.

Rudolf, Miriam. 2008. Einfluss von Besatzdichte und Einstreumaterial auf die Pododermatitis bei Mastputen. Inaug. Diss. FU Berlin.

Sanotra, G.S., Lund, J.S., Ersøll, A.K., Petersen, J.S. and Vestergaard, K.S. (2001) Monitoring leg problems in broilers: a survey of commercial broiler production in Denmark. World's Poultry Science Journal, 57:1, 55-69, DOI: 10.1079/WPS20010006

Savory, C. J. 1975. A growth study of broiler and layer chicks reared in single-strain and mixed-strain groups, Brit. Poultry Science. 16:315–318.

Scholtyssek, S. 1973. Zur Frage der Besatzdichte in Broilerherden, Archiv. Geflügelk. 35:235–239.

Scholtyssek, S. and G. M.Grashorn. 1989. Laufböden in der Broilermast, Züchtungskunde. 61:152–163.

Schrader, L. (2013): Tierschutz in der Nutztierhaltung – wo liegen Chancen und Grenzen? In: Züchtungskunde 85, S. 34–39.

Schwean-Lardner, K., B. I. Fancher, and H. L. Classen. 2012. Impact of daylength on the productivity of two commercial broiler strains, Br.Poult.Sci. 53:7–18. doi: 10.1080/00071668.2012.659652.

Shanawany, M. M. 1988. Broiler Performance under high stocking densities, Br.Poult.Sci. 29:43–52.

Sørensen, P. 1992. The genetics of leg disorders. In: Whitehead, C.C. (ed.) Bone biology an Skeletal Disorders in Poultry. Carfax Publishing Co., Abingdon, UK,:213–229.

Sørensen, P., G. Su, and S. C. Kestin. 1999. The effect of photoperiod:Scotoperiod on leg weakness in Broiler chickens, Pou. 78:336–342. doi: 10.1093/ps/78.3.336.

Steenberg, B. 2012. Introduction to the Danish broiler sector. Facts about the production of poultry meat in Denmark. p14. Landbrug og Foedevarer.

Su and Sørensen loc. cit. Muir, W. M., and S. E. Aggrey. 2003. Poultry genetics, breeding and biotechnology. CABI Publishing, Wallingford.

Sultana, S., M. R. Hassan, H. S. Choe, and K. S. Ryu. 2013. The effect of monochromatic and mixed LED light colour on the behaviour and fear responses of broiler chicken, Avian Biol Res. 6:207–214. doi: 10.3184/175815513X13739879772128.

Swalander, M. 2012. Balanced breeding of turkeys for health and welfare. Lohmann Information 47(1), 43-48.

Thomsen, M. G. 1989. Lysprogammet og foderstructurens inflydelse pa slagtekyllingers adfaersmonster., Statens Husdyrbrugsforsog. Meddelse Nr. 736, Kopenhagen, Dänemark.

Webster, A. B., B. D. Fairchild, T. S. Cummings, and P. A. Stayer. 2008. Validation of a Three-Point Gait-Scoring System for Field Assessment of Walking Ability of Commercial Broilers, The Journal of Applied Poultry Research. 17:529–539. doi: 10.3382/japr.2008-00013.

Wiedmer, H., and R. Hadorn. 1998. Revision Tierschutzverordnung. Kurzmast-Besatzdichten lassen, Schweizerische Geflügelzeitung. 2/98:10–15.

Xie, D., Z. X. Wang, Y. L. Dong, J. Cao, J. F. Wang, J. L. Chen, and Y. X. Chen. 2008. Effects of monochromatic light on immune response of broilers, Poult. Sci. 87:1535–1539. doi: 10.3382/ps.2007-00317.

Youssef, I. M. I., A. Beineke, K. Rohn, and J. Kamphues. 2011. Effects of litter quality (moisture, ammonia, uric acid) on development and severity of foot pad dermatitis in growing turkeys, Avian Diseases. 55:51–58.

Zubair, A. K., and S. Leeson. 1996. Compensatory growth in the broiler chicken. A review, World's Poult.Sci.J. 52:197–201.

Zuidhof, M. J., B. L. Schneider, V. L. Carney, D. R. Korver, and F. E. Robinson. 2014. Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 20051, Poult. Sci. 93:2970–2982. doi: 10.3382/ps.2014-04291.

Do BROILERS BENEFIT from elevated structures?

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Julia Malchow has finished her PhD at the Institute of Animal Welfare and Animal Husbandry (FLI) on the behaviour and housing requirements of dual purpose chickens. She obtained her master degree in livestock science at the University of Rostock. In addition to her knowledge in the behaviour and housing of chickens she has experience with learning tests and variety of techniques such as with infrared thermography. Currently she is working in the HealthyLivestock EU project at the Institute of Animal Welfare and Animal Husbandry.

ABSTRACT

Commercial broiler chickens are usually kept in barren housing environments which contain only the most necessary equipment such as feeder and drinker lines and littered floor.

Providing elevated structures in modern broiler husbandry can lead to certain advantages such as reduction of the stocking density, drying of the litter, improvement in leg health and support of species-specific behaviour (perching, exploration, etc.).

In order to enrich the housing environment of broilers with elevated structures without compromising the health and welfare, the shape, height and design of these elements must be adapted to the age and physical abilities of the broilers.

In three successive experiments, three breeds differing in growth rate were investigated to determine whether and which shape of elevated structure the chickens use. In addition, the utilization of elevated structures on animal welfare was investigated.

Broiler chickens are highly motivated to use elevated platforms from the first week of life onwards, depending on growth rate. Low levels were preferred by fast growing and high levels by slow growing broiler chickens.

Elevated structures can increase activity and improve walking ability. Thus, elevated structures enhance the natural behaviour of walking and resting and thus, positively influence animal welfare.

Keywords: Broilers, welfare, behaviour, perches, elevated platforms.

INTRODUCTION

Night roosting, i.e. the overnight stay on an elevated sleeping place, belongs to the natural behaviour of the Red Jungle fowl. The Red Jungle Fowl is regarded as the wild ancestor of the domestic chicken and is still abundant in the jungles of South East Asia. Domestic chickens, adults as well as chicks, show the same behavioural repertoire with respect to their preference to roost overnight on elevated places.

With the onset of dusk chickens seek elevated places to roost, that can be suitable perches or alternatively other elevated furnishing elements. According to the EU directive 1999/74/EC, this natural behaviour should be supported and therefore specific perches are required in housing systems for laying hens. However, for pullets and meat chickens no respective legal requirements are specified with regard to elevated structures. For pullets, perches are recommended from the first day of life on and become only obligatory from the 35th day of life on, when all chicks must be able to find a place on the perches.

Commercial broiler chickens are usually kept in barren housing conditions, which contain only the most necessary equipment such as feeders, drinkers and littered floor.

Environmental enrichments for broilers are usually only offered as litter, e.g. wood shavings, wooden or straw pellets or alternative substrates. In this environment, broiler chickens are able to fulfil their requirement for food, water and certain behaviours such as scratching, pecking or dustbathing.

However, previous studies showed that broiler chickens are motivated to search and use elevated resting places. Providing such elevated structures in modern broiler husbandry can have certain advantages such as reduction of stocking density, drying of the litter, improvement of leg health and support of species-specific behaviour (perching, exploration, etc.).

In order to be able to enrich the housing of broilers with elevated structures without compromising the health and welfare, the shape, height and design of these elements must be adapted to age and physical abilities of the birds. In addition, the characteristics of different breeds should also be taken into account.

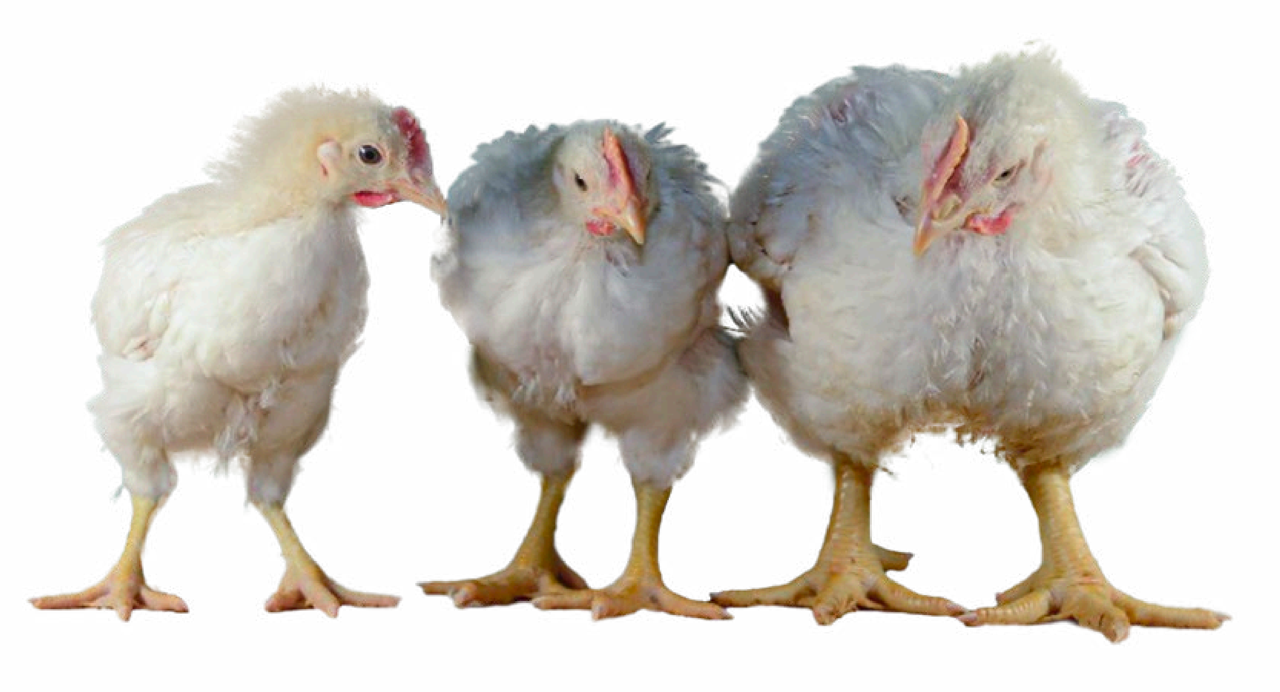


Figure 1. *Male birds of three strains at the 5th week of age: modern hybrid layer breed "Lohmann Brown" (LB), dual-purpose breed "Lohmann Dual" (LD) and commercial broiler breed "Ross 308" (from left ©FLI ITT)*

As part of the Integhof project (*Integhof, 2019*), scientists of the Institute of Animal Welfare and Animal Husbandry (ITT) of the Friedrich-Loeffler-Institut (FLI) in Celle, aimed to clarify and specify these requirements for dual-purpose male chickens "Lohmann Dual" (LD, ***Figure 1***).

Male chickens from two other breeds, "Ross 308" (Ross) and hybrid layer breed "Lohmann Brown" (LB) were used to compare the usage of the elevated structures on animal welfare.

During the test period, male chickens of these three different breeds were kept in four compartments each (12 compartments in total). The results of three experiments will be reported below.

METHODS, RESULTS AND DISCUSSION

Experiment 1

Comparison of perches vs. elevated perforated platforms

In the first part of the study, perforated platforms (mesh size: 19 x 19 mm, bridge width: 10 mm, Big Dutchman International GmbH, Vechta, Germany) and perches (mushroom-shaped, width: 6 cm, LUBING Maschinenfabrik Ludwig Bening GmbH & Co. KG, Barnstorf, Germany) were installed at three different heights. They could be accessed via ramps (same material as platform, width: 30 cm; angle: 35°, ***Figure 2***).

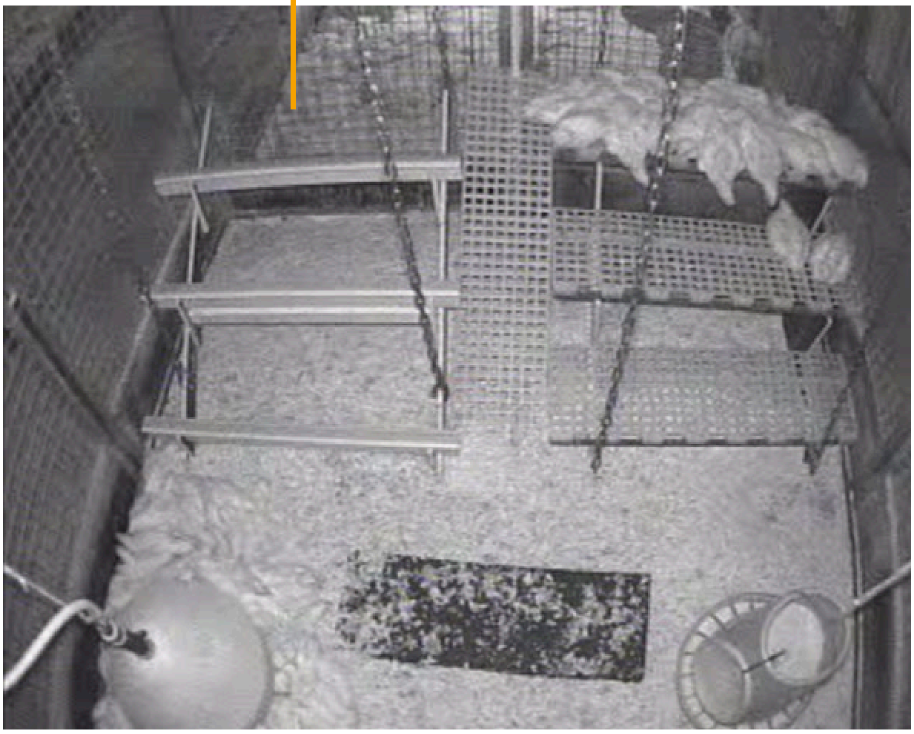


Figure 2. *Comparison of perches and raised platforms in Experiment 1: Lohmann Dual male chickens on the elevated platforms in the fifth week of life at 10.00pm (dark period) (©FLI ITT)*

With regard to locomotor activity of individuals, improvements were found in LD and Ross as a result from the enrichment through the elevated structures. LD chickens from the enriched compartments showed a better walking ability compared to the birds from the non-enriched control groups. Plumage condition or foot health were not affected by the elevated structures.

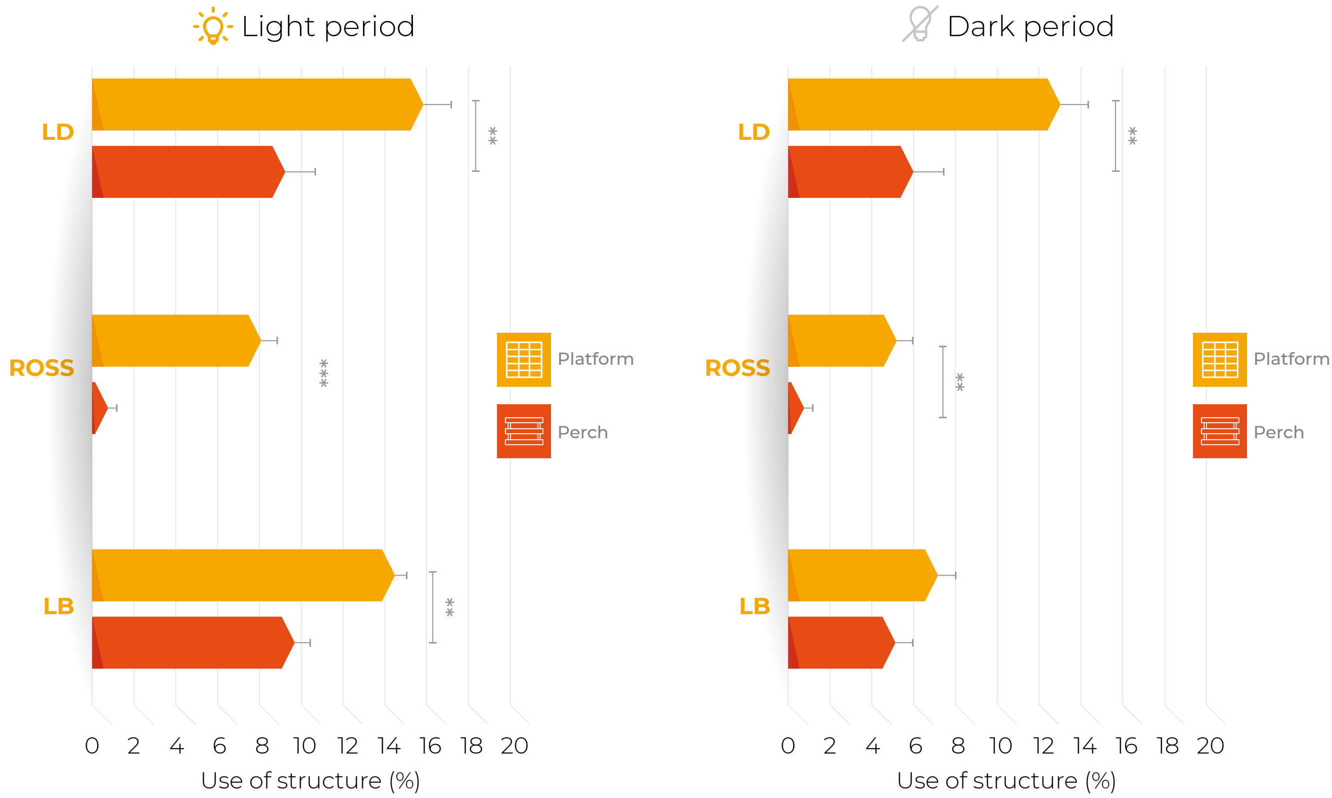


***Figure 3.** Use of perches and elevated perforated platforms over the entire observation period. Differences between the structural shapes are marked by asterisk (* P = 0.05, ** P = 0.01, *** P ≥ 0.001)*

A total of 650 male chicks of the three different breeds were used. Fifty birds each were randomly allocated to 12 compartments (4 compartments per breed). The birds' preference for the different elevated structures was determined for the later studies.

All three strains showed an increasing use of the elevated structures (highest average use: LD ≈ 34%, Ross ≈ 14%, LB ≈ 34%). Only the Ross 308 broiler chickens showed a decreasing use of the elevated structures from the fourth to the fifth week of life during the light period.

Throughout the study period, a clear preference for platforms over perches was observed for all three breeds (***Figure 3***).

Experiment 2

Comparison of different heights of the elevated structures

Because of the preference of perforated platforms, only these were offered as perching opportunities in the following studies.

To test the effect of elevated structures on animal-related parameters such as locomotor activity, walking ability and plumage condition, half of the compartments (6 compartments – groups of 50 chicks each, two compartments per breed) were equipped with platforms (MIK International GmbH & Co. KG, Werl, Germany) at three different heights (10 cm, 30 cm, 50 cm).

The frequency of use by the animals of the different levels was analysed. The slow growing breeds (LD and LB) preferred the highest levels while the fast growing breed (Ross) preferred the two lowest levels (***Figure 4***).

With regard to locomotor activity of individuals, improvements were found in LD and Ross as a result from the enrichment through the elevated structures. LD chickens from the enriched compartments showed a better walking ability compared to the birds from the non-enriched control groups. Plumage condition or foot health were not affected by the elevated structures.

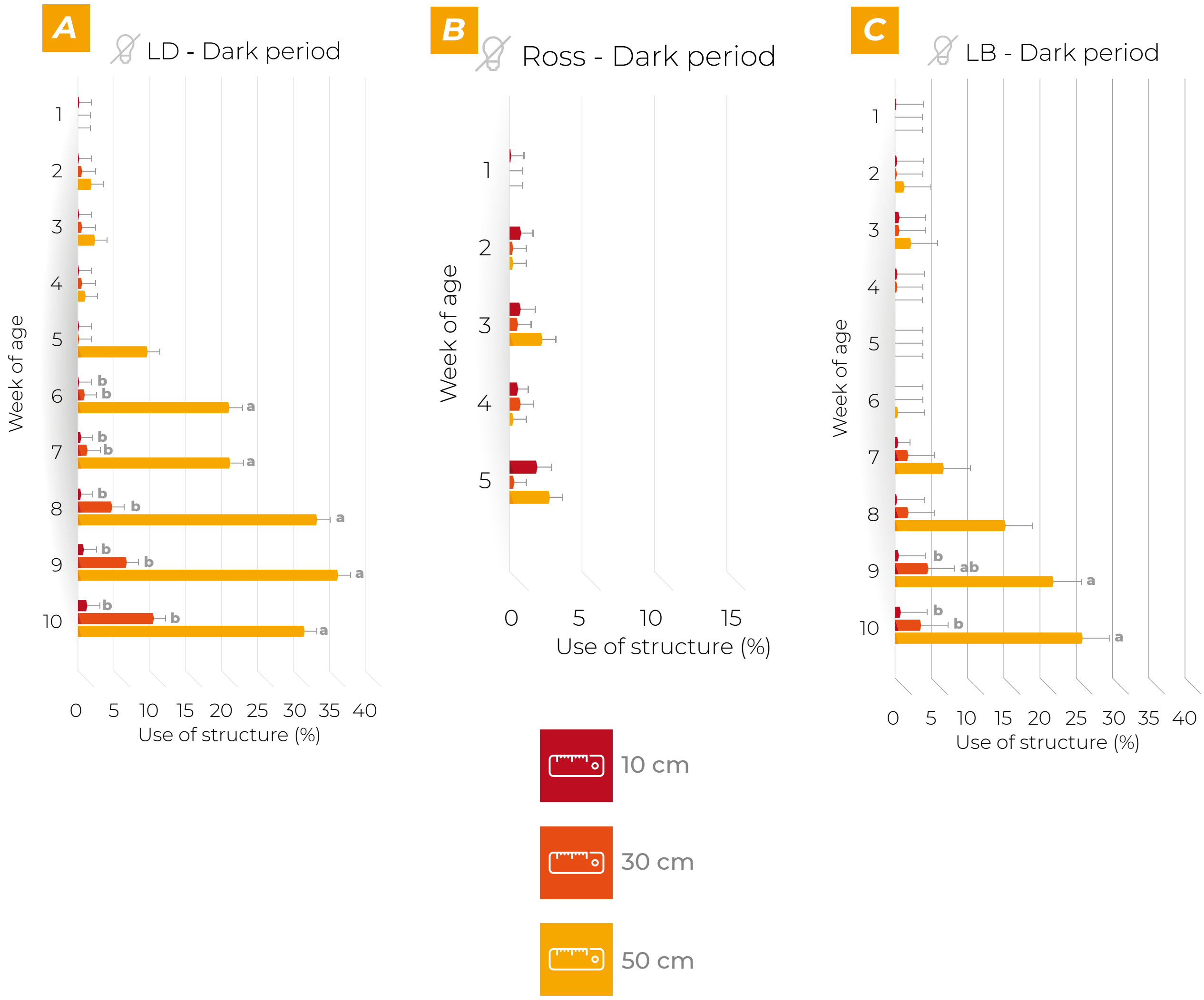


Figure 4. *Use of raised platforms in response to height during the dark period by three strains:*

***A** – Lohmann Dual*

***B** – Ross 308*

***C** – Lohmann Brown*

Differences between the structural shapes are marked by different letters (P < 0.05)

Experiment 3

Supply of space

In the third and final part of the study, six compartments per breed (three per breed), i.e. Ross and LD were kept. In half of the compartments the chickens were offered elevated platforms at a height of 50 cm with access via a widened ramp (from 30 cm in the previous experiments to 60 cm) and lower angel (from 35° in the previous experiments to 24°).

In the other half compartments (6 compartments; three per breed, groups of 50 chicks each), no elevated platforms were offered. Hence the usable space was 20% smaller than in the compartments with raised platforms.

Animal related parameters (e.g. walking ability, plumage condition, foot health) and planimetric data of the space covered by the animals on the elevated structure were measured.

To date, only a descriptive evaluation of the use of elevated structure has been done. In comparison with the two previous experiments (***Experiment 1***: 14%; ***Experiment 2***: 4%), Ross broilers showed an increase in use of the elevated platform of 18%. In LD 70% of the birds were observed on the elevated structures at the end of the growing period.

The use of the total area differed between the two breeds due to the different body areas and the different utilisation of the elevated structures.

In summary, it seems that fast growing birds require a smaller elevated area compared to slower growing breeds (***Figure 5***).

Based on our results, we recommend an elevated platform for at least 20% of broilers like male Ross 308, while dual purpose males like Lohmann Dual should be given elevated platforms for at least 50% of the chicks.

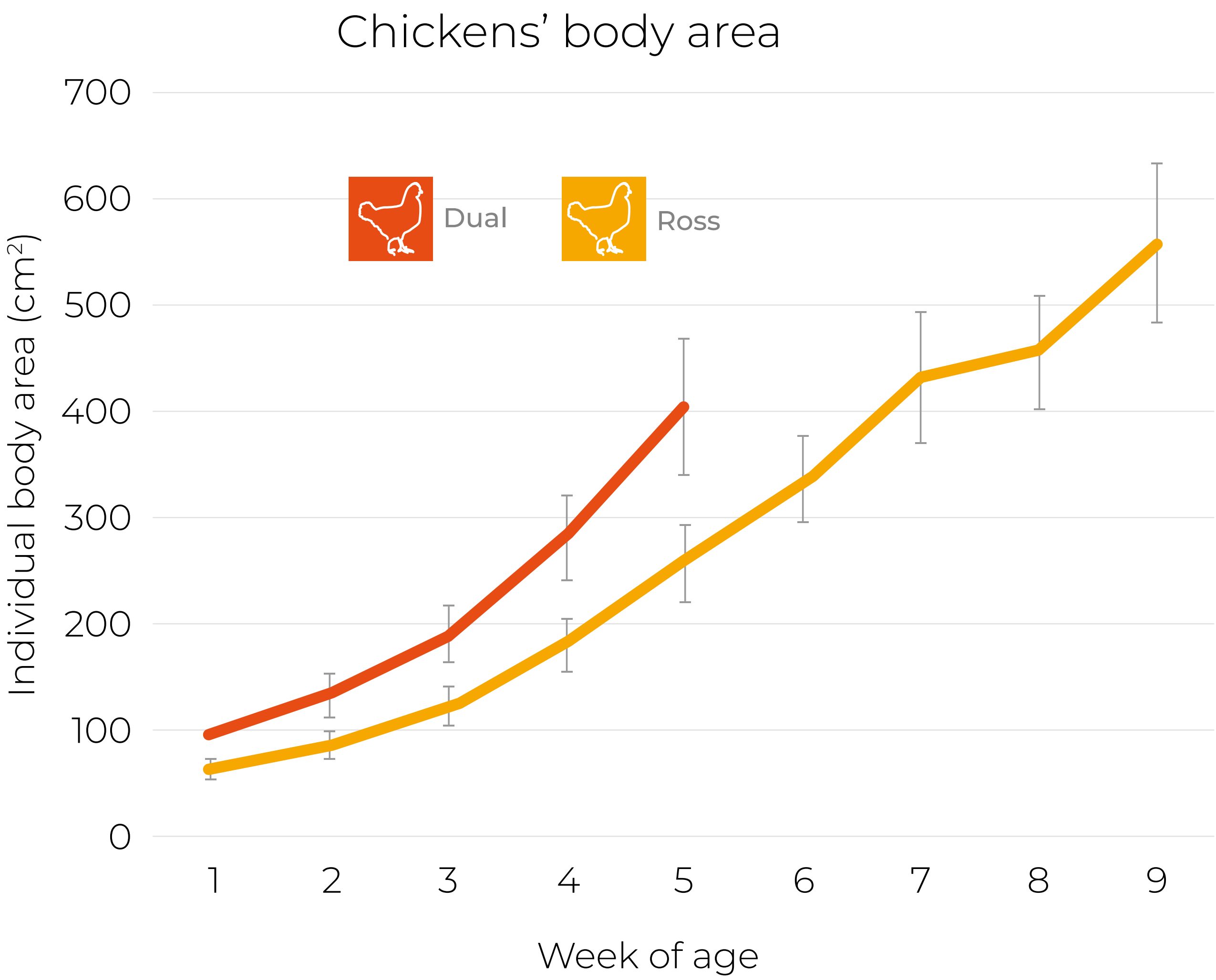


Figure 5. *Development of individual body area from 1 to 5 weeks (Ross) and 1 to 9 weeks of age (Lohmann Dual)*

CONCLUSIONS

Taken together, it could be shown that broiler chickens differing in growth rate are highly motivated to use elevated platforms from the first week of life on.

However, to use elevated platforms, the mesh size must be chosen correctly to minimise the risk of injury.

Width and slope of the ramp also play an important role for an optimal use of the elevated structure, especially in fast growing breeds.

Elevated structures can increase activity and improve walking ability.

There was no increased dirtiness of the plumage of the birds below the structures. In addition, elevated platforms divide the available space into distinct activity and resting areas.

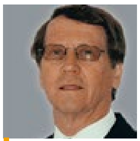
A height of 50 cm of the elevated elements does not negatively affect the farmers' animal control. Thus, elevated structures enhance the natural behaviour of walking and resting and thus, positively influence animal welfare.

References. *Integhof (2019) (https://www.fli.de/de/institute/institut-fuer-tierschutz-und-tierhaltung-itt/forschungsbereiche-arbeitsgruppen/ag-legehennen/forschungsprojekte-einzelansicht/?tx_news_pi1%5Bnews%5D=469&cHash=1dbc207f70ddb6fc582d9f52541e0952*

Malchow, J., Berk, J., Puppe, B., Schrader, L. (2018). Perches or grids? What do rearing chickens differing in growth performance prefer for roosting? Poultry Sci. 98(1):29-38, DOI: 10-3382/ps/pey320

Malchow, J., Puppe, B., Berk, J., Schrader, L. (2019). Effects of Elevated Grids on Growing Male Chickens Differing in Growth Performance, Frontiers in Veterinary Science 6:203, DOI: 10.3389/fvets.2019.00203

Enrichment for broilers and turkeys – from theoretical consideration to practical application



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Abstract

In the debate on the welfare of broilers and turkeys environmental enrichment has become a major issue. Most label production programs request occupation objects in addition to litter.

Diverse methods of enrichment have recently been developed and tested. Enrichment strategies aim at increasing the intensity and variability of behaviours.

They include different materials, such as perches, raised platforms, vertical panels inside the pens, pecking devices and various feeding and lighting programs. Raised platforms are preferred over perches in fast growing breeds.

Stimulation of foraging activities through the presentation of supplementary whole grain feeding shows little effect as long as compound feed is available. The use of perches and raised platforms declines with age.

Nevertheless even fast growing breeds of broilers and turkeys show the motivation to use raised levels for resting, especially during night.

Enrichment tends to improve activity and to reduce leg problems. The acceptance of devices which are expected to stimulate pecking activities, such as hay and straw baskets, pecking blocks, strings and plastic objects is highly variable and the birds' interest often declines after a short time.

Temporary presentation of enrichment devices and/or simultaneous presentation of different enrichments increase the interest and response of the birds to these stimuli.

Special feeding programs, such as sequential presentation of different diets and light programs can stimulate the activity and improve the leg conditions. Enrichment in broilers and turkeys has obviously no significant effect on performance.

First cost estimates for different enrichment measures used in commercial turkey farms varied between 0.12 and 0.68 € per bird. Growing information on various forms of enrichment enables farmers to select the most suitable forms for given management systems.

Keywords: Broilers, turkeys, enrichment, welfare, economics.

INTRODUCTION

Broilers and turkeys are traditionally kept under monotonous environmental conditions, which compromise bird welfare due to inactivity, restriction of the behavioural repertoire and various health hazards. Recent development of welfare labels request enrichment devices in order to stimulate the expression of a wide spectrum of behaviours and to improve the physical and psychic conditions of the birds. Consequently there has been a rapid development of studies on environmental enrichment in boilers from the 1990s onwards. A literature search for reviewed scientific articles on "environmental enrichment" and "broilers" using Scopus showed a sharp progression from 2016 onwards **(Figure 1)**.

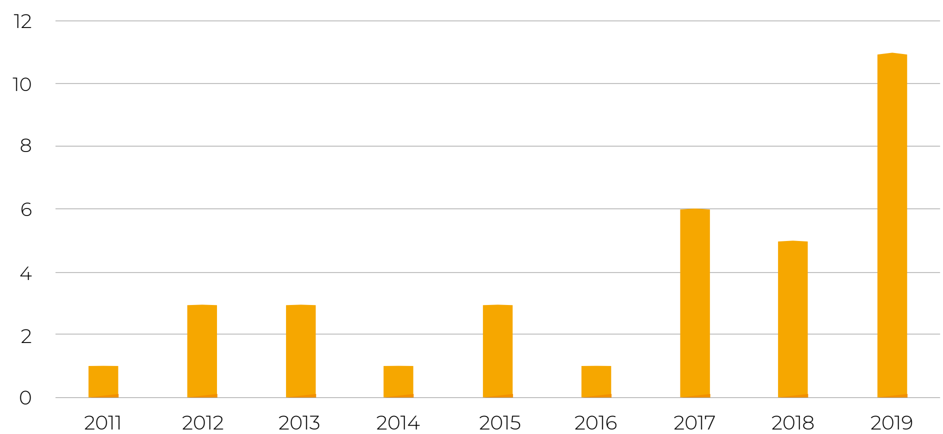


Figure 1. *Number of published articles in reviewed scientific journals from 2011 to 2019 (Scopus search, February 2020)*

It is generally accepted that adequate external stimuli are a prerequisite for normal physiological and psychological development of humans and animals. Deprivation of stimuli impairs the neuronal organisation of the nervous system and causes serious behavioural problems (Prescott, 1971). Experiments with primates have shown that lack of somatosensory stimulation leads to unsocial behaviours, problems to experience positive emotions and – under extreme conditions – to death. Lack of environmental stimulation can also produce behavioural stereotypies.

Intensive husbandry systems for broilers and turkeys are charcterized by uniform, barren environment, but provide more stimuli than the experiments under which the above-mentioned problems have been demonstrated. Nevertheless, many behavioural problems of farm animals are considered the result of the monotonous environment.

Physical restriction and lack of structural elements of the environment does usually not allow full expression of the behavioural repertoire shown under natural conditions. Whether the expression of the full behavioural inventory is essential for the welfare of the birds is still debated among scientists. It is assumed that scratching, dustbathing, exploration (litter pecking and walking), and perching are indicators of wellbeing (Riber et al., 2017).

Dustbathing for instance is supposed to be important for the maintenance of the feather cover. Perching and fear responses are essential for the protection of in wild birds against predators. Foraging is an essential behaviour in free-living birds to find food. These behaviours have lost their function under husbandry conditions.

In indoor systems, chickens are not exposed to adverse climatic conditions and predators and feed is provided regularly in feeders. The fact that chickens perform the above-mentioned behaviours, regardless of the prevailing environment, has led to the assumption that the performance as such of these behaviours may have a rewarding effect. This is the theoretical basis for so-called “behavioural needs”.

Hence, provision of the opportunity for foraging, dustbathing and perching is considered essential for the wellbeing of domestic chickens.

In the public opinion, animal welfare not only requires the availability of substrates, which allow natural behaviours. Welfare implies also the perception of positive emotions (Newberry, 1995). Positive emotions are difficult to assess. Indicators of positive emotions are play-like behaviours, such as frolicking with or without objects, sparring and positive social interactions.

Environmental enrichment is assumed to stimulate these behaviours and, thus, improve welfare (Vasdal et al., 2019).

Enrichment has also been shown to reduce fear as negative emotional state. Perches, shelter and loose strips seem to enhance the resilience of birds towards different stressors, such as loud heavy metal music and irregular light schemes (Zidar et al., 2018). Under enriched conditions the birds showed also more explorative behaviour, improved problem solving in a detour test and a “positive attitude” in a bias judgement test when exposed to stressors.

Consequently, environmental enrichment has become an essential aspect of animal welfare regulations and particularly of voluntary welfare labels (Bessei, 2018).

Enrichment measures should be attractive and stimulate desirable behaviours, prevent undesirable behaviours and damages, and finally, should be applicable under practical husbandry conditions (Jones, 2004). Various approaches of enrichment in broilers and turkeys include: structural equipment, lighting and feeding programmes.

These programs aim at improving the variability of behaviours and stimulating locomotor activity.

The latter is of special importance with regard to prevention of leg problems (Reiter and Bessei, 2009; Djukic et al. 2004). Provision of free range and a veranda showed positive effects on health and welfare in growing turkeys (Berk et al., 2018). Enrichment materials do not stimulate behavioural activities in all cases. Raised platforms and large straw bales, for example, enhanced resting and reduced locomotion in turkeys (Letzguss, 2010). Baxter et al. (2019a,b) did not find a positive effect of enrichment on play behaviour.

There is a multitude of reports on different enrichment methods, which have been tested in experimental stations, and on commercial production units.

However, there is still a lack of information on the practical application and the economics of enrichment for broilers (Riber et al., 2017). The present paper gives an overview of the most important enrichment systems and economical aspects of enrichment under commercial conditions.

STRUCTURAL ELEMENTS

Litter

Broilers and turkeys are usually kept on litter, which is considered as a basic means to allow exploration, scratching, pecking and dust bathing. The absence of litter was one of the most important arguments for the ban of conventional cages for laying hens. To be functional with regard to scratching and pecking behaviour, litter should be dry and friable.

However, under practical conditions litter becomes often wet and sticky and does not provide adequate materials for behavioural stimulation. Wet litter has been recognized as main factor causing footpad dermatitis in broilers and turkeys (Mayne et al., 2007; Youssef et al., 2011).

The establishment of special areas with dry sand increased the activity of broilers during the first weeks of live (Leterrier et al., 2001). This effect, however, disappeared at the end of the growing period.

Various different types of litter, like wood shavings, peat, oat hulls and straw pellets have been tested as enrichment materials. Peat and oat hulls were found to be particularly effective in stimulating dust-bathing behaviour in broilers (Baxter et al., 2018). There was, however, no effect of litter as enrichment on the leg conditions.

Perches and raised platforms

Under natural conditions, chickens and turkeys perch on trees or on other raised places. This behaviour is an important means to escape predators while resting and sleeping. Hence perching is considered as essential behavioural requirement.

It is generally acknowledged that domestic chickens and turkeys have a strong preference to use raised locations.

The use of this enrichment equipment may enable the birds to escape from crowded, wet and poorly ventilated litter areas. Moving up and down in the different levels may also strengthen the skeleton system and reduce leg problems.

While the installation of perches is compulsory for layers in EU countries, there is no legal regulation for broilers and turkeys so far. There is, however, increasing interest of welfare labels to present raised places for meat producing birds.

Consequently this aspect is being dealt with by research institutes and practical broiler and turkey producers. Research aspects of elevated structures for broilers are presented in detail by J. Malchow in this edition (pages ...).

Attempts to solve the problems under practical conditions are presented in the following.

Transport boxes or bags filled with litter materials may be used to provide raised places in broiler houses. Observations in commercial farms have shown that these places are frequently visited and used by the chicks for resting and pecking **(Figure 2)**.

Figure 2 *Chick`s transport boxes (left) and bags filled with straw pellets or other litter material (right) are being used as raised platforms*

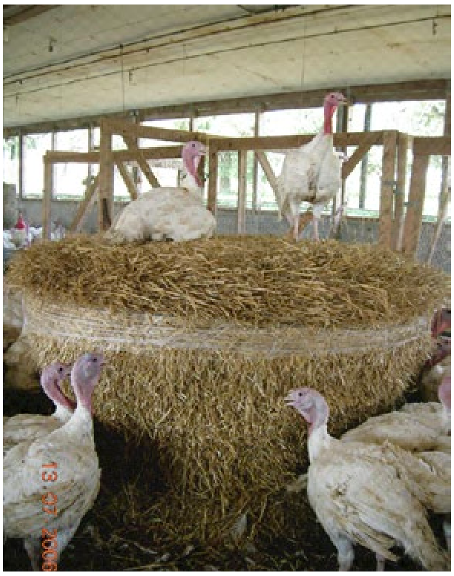
The material is worn down as the chicks grow older and the remaining is being integrated in the litter.

Larger and more long-lasting platforms of wood or metal have been constructed for older broilers and turkeys **(Figure 3 A,B)**.

Figure 3 *Raised platforms are used extensively by turkeys (left) and broilers (right) during day and night*

Ramps are usually attached to facilitate access. These constructions have to be cleaned and disinfected after each flock. Large bales of straw are also used as raised locations by broilers and turkeys **(Figure 4)**. They are integrated in the litter through pecking and scratching and the remaining is being removed with the litter.

Figure 4
Large straw bales are being used for perching and pecking



There is a controversial discussion whether raised platforms and straw bales fulfil the behavioural requirement of the birds for resting and sleeping (Schrader et al., 2016). Some authors argue that clasping around the perch is essential for adequate resting and sleeping **(Figure 5)**.

Figure 5
Suspended plastic perches allow the birds to clasp around the perch and can be adapted to size of the birds

Other authors stress the importance of a raised locations, independent of the footing material, and raised platforms may fully substitute perches. This argument is supported by choice experiments which showed that heavy broilers and turkeys prefer platforms over perches (Norring et al., 2016; Malchow et al., 2018a; Strassmeier, 2007). There is a debate whether the additional space provided by platforms may be accepted as "available" space. This aspect is important from the economical and welfare point of view. The use of the raised areas may allow higher stocking rates of broiler and turkey houses, and thus, reduce housing costs. In most welfare programs this space has to be provided as supplement to the minimum available space.

Figure 6
Space underneath the platform is used by subordinate birds to avoid aggressive pecks

The area underneath the platforms can be used by the subordinate birds to escape from aggressive attacks of dominant pen mates and thus contributes to their welfare **(Figure 6)**.

There is no general rule concerning the minimum height of perches or platforms. Malchow et al. (2018b) tested the preference of different broiler breeds for perches and grids at heights of 10, 30 and 50 cm. The highest level was the most preferred. Berk and Hahn (2000) reported that growing turkeys made better use of perches at intermediate height of 40 cm versus 20 and 60 cm height. Davies and Weeks (1995) could increase the use of perches by broilers when their height was continuously adjusted to the size of the birds. Sloped designs where one end of the perch is on ground level and the other end is raised enable the birds of different size to access the perch and to choose their preferred height **(Figure 7)**.

Scholtyssek and Grashorn (1989) used symmetric ramps with an integrated perch on the highest point. This perch was used intensively for resting.

Moving up and down between different levels may improve the condition of wings and leg bones.

Figure 7 *Broad perches which are raised at one end can be accessed by broilers from day-old*

The use of raised locations, however, bears risks of developing dermatitis of the breast skin and foot pads (Bokkers and Koene, 2003).

The use of raised levels is restricted by the body weight and poor agility of fast growing birds. Therefore, the expected expression of positive and negative effects of this type of enrichment depends on the use of the enrichment devices. Perches were used by up to 20 % of the broilers, when perch height was continuously adjusted to the bird size (Davies and Weeks, 1995). In turkeys the use of perches varied between 1 and 10 % (Matrenchar et al., 1999). Reports on the effect of raised locations on welfare are not consistent. Mench et al. (2001) found improvement of the leg bones and the behaviour of broilers, which were given the opportunity of climbing and perching. Raised platforms improved gait scores significantly (Kaukonen et al., 2017), and ramps between feeders and drinkers improved the leg bone conditions of broilers (Scholtyssek and Grashorn, 1989). Positive results of raised platforms and straw bales as resting places on tibia bones of turkeys have also been reported by Letzguß (2010). Using similar enrichments, Cottin (2004) found better plumage scores and better walking ability in growing turkeys. In other studies, there were only minor or no effects of these structural enrichment components on welfare related criteria (Balog et al., 1997; Bizeray et al., 2002; Bench et al., 2016).

VERTICAL PANELS

Broilers prefer resting near walls. Based on this observation, vertical panels as structural enrichment elements have been tested (Newberry and Shackleton, 1997; Rodrigez-Aurrekoetxea et al., 2014; 2015). The panels led to more regular distribution of the birds over the whole pen and a better use of the central areas. Buijs et al. (2010) observed less disturbances of the birds by their pen mates through vertical panels. There was no effect of vertical panels on performance, footpad dermatitis and fluctuating asymmetry as indicators of stress. Farmers of label broiler production in France, who use suspended panels regularly, have confirmed this effect (personal communication; **(Figure 8)**.

Figure 8 *Vertical panels suspended from the ceiling lead to uniform distribution of broilers while resting*

PECKING DEVICES

Figure 9 a,b
Turkeys show little interest in coloured plastic bottles (top) blue cannisters (below) are highly atractive (by courtosy H. Meyer, Kartzfehen, Germany)

Figure 9 c,d
Turkeys and broilers show littel interest in strings fixed at the feeder lines

Figure 9c

Figure 9d

While litter stimulates pecking as well as scratching and dustbathing behaviour, there exists a multitude of devices, which are designed to attract pecking behaviour only. This is supposed to reduce feather pecking and cannibalism in slow growing broilers and in turkeys (Sherwin et al., 1999; Crowe and Forbes, 1999). Strings, CD-discs, plastic bottles or canisters, baskets filled with hay or straw, straw bales or different other objects have been used experimentally or in commercial production systems **(Figures 9 a - g)**.

Laying hens use strings extensively as pecking objects. Broilers, in contrast, showed little interest (Bailie et al., 2018). The use of hay baskets has proved to be highly variable and there was no effect on feather pecking and cannibalism in turkeys (Letzguß, 2008). The interest of turkeys and broilers for enrichment objects is mainly driven by novelty, and the birds loose interest in the objects within a short time of continuous presentation. Therefore, it has been proposed to present the objects only temporarily and/or to frequently change the type of pecking objects.

***Figures 9 e,f,g** Hay baskets stimulate pecking and eating; the same basket filled with multicolour plastic balls is ignored; CDs attract the attention of turkeys, the birds may, however, distroy through vigorous pecking*

The presentation of edible objects has been considered more efficient in sustaining pecking of the objects. Pecking blocks containing whole grain have shown to be highly attractive for longer periods. They were used extensively by the birds and had to be replaced several times during the growing period.

FEEDING PROGRAMS

Broilers are usually fed a uniform feed as pellets or crumbles, which leads to satiation in a short time. Therefore, attempts have been made to stimulate pecking, walking and scratching through distribution of whole grain as feed supplement in the litter. This method was not successful as long as pelleted feed was available in the troughs. Higher activity was achieved when the whole pelleted diet was scattered in the litter (Jordan et al., 2011). Pichova et al. (2016) have reported similar results. The distribution of whole wheat in the litter did not increase the activity of broilers. Only the distribution of highly attractive mealworms led to a short term increase of activity. In turkeys the presentation of whole wheat grain reduced feather pecking (Berk et al., 2017). Sequential feeding is another method to enrich the environment through feeding. Bizeray et al. (2001) fed diets differing in lysine content in the morning and in the afternoon. This system increased litter pecking and walking activity. Unfortunately, growth was negatively affected. Reiter and Bessei (2009) increased the distance between feeder and drinker from 2 to 12m. Performance criteria were not impaired, mortality was reduced by 2 % and leg conditions were improved. The latter effect was obviously due to an increased locomotor activity.

LIGHT

In the past, continuous light or quasi-continuous light (23 h light : 1 h dark) was the standard lighting program in most windowless broiler houses. It resulted in a low level of locomotor and feeding activity throughout the 24 hours period. This program has shown highest performance in earlier broiler breeds (Morris et al., 1967). However, continuous and quasi-continuous light prevent the development of circadian rhythms and cause enlargement of the eyeballs. Intermittent lighting programs using alternating short light and dark periods, such as 2 h light : 2 h dark, or 1 h light : 3 h dark, show similar effects as continuous light (Onbasilar et al., 2007; Olanrewaju et al., 2018). Interruption of the light phase through extended dark periods clearly improved the leg conditions but reduced growth rate, especially in short growing periods. The reduced growth could only be compensated with extended growing time (Thomsen, 1989). Schwean-Lardner et al. (2013) showed that in modern broiler lines periods of 4 to 8 hours of continuous darkness not only prevent the above-mentioned negative effects on welfare but also represent optimum conditions for growth and feed conversion.

Meyer et al. (2019) presented a novel method of enrichment using laser light. Red laser dots were projected on the floor of broiler pens 4 times a day for four minutes. This procedure stimulated physical activity of the birds. There was no effect on walking ability.

COMBINATION OF ENRICHMENT ELEMENTS

The combination of different enrichment devices increases the environmental complexity and may show a higher impact on welfare related criteria than single enrichment devices. Hence, several welfare programs for broilers and turkeys require different types of enrichment simultaneously.

The combination of several enrichment elements has been studied in recent experiments. The results are, however, not consistent with regard to welfare criteria.

The availability of day light and straw bales did not reduce the interest in supplementary stimuli like strings (as pecking devices) and perches (Bailie and O`Connell 2014). The combination of strings and perches actually caused a reduction in locomotor activity, whereas the walking ability was slightly improved. Perches and dustbathes combined showed no effect on activity and play behaviour, but reduced fearfulness in broilers more efficiently than raised platforms only (Baxter et al., 2019). Oat hulls as supplementary enrichment to straw bales improved the gait score in broilers, but showed no effect on the activity of broilers (Baxter et al., 2018). Vasdal et al. (2019) provided broilers with peat (as preferred substrate for dustbathing), bales of alfalfa hay and elevated platforms.

The enriched birds showed higher activity in various different behaviours and there was a non-significant tendency of improvement in gait score. The combination of peat and raised platforms reduced fearfulness, but showed no effect on the activity level and play behaviour.

Light seems to play a particular role in combination with enrichment.

Combination of wood shaving bales, perches and pecking devices reduced the activity of commercial broilers in conventional windowless houses as compared with an un-enriched control in conventional window-less broiler houses (de Jong and Ginnink, 2019). Positive effects of enrichment on the behavioural activities, such as exploration, foraging and walking, were only observed in combination with natural light. This confirmed earlier reports of Bailie et al. (2013), where the effect of natural light on gait score was greater in commercial broilers than the effect of straw bales. The combination of straw bales and natural light showed significantly longer latency to lie than straw bales in windowless conditions.

The stimulating effect of combined enrichment (perches, pecking stones and straw bales) on locomotion, foraging and comfort behaviour of commercial broilers may have been due to access to natural

ECONOMICS OF ENRICHMENT

There is little information on the economics of enrichment in commercial broiler production. Goczik et al. (2017) estimated the economic effect of six different enrichment methods in broilers using a normative economic model.

Three of the enrichment methods, meal feeding, sequential feeding and feeding whole wheat showed a higher gross margin and net return on management than the unenriched production system.

It was assumed that the enrichment procedures reduced leg problems and mortality. On the basis of practical experience, the costs of enrichment in a flock of 4000 male turkeys has been estimated by Glawitz et al. (2014; unpublished). The results are shown in table 1.

All enrichment objects are available commercially and average market prices have been used for the calculation. The amount of objects or material is not standardized so far. It varies in the present calculation from 25 pecking blocks to 8 large hay baskets for a flock of 4000 male turkeys.

According to recommendations of an animal welfare program in Germany the minimum requirement is one enrichment object for 400 m² and 150 m² pen area in turkey and broiler pens respectively.

As assumed in the present economic calculation, pecking blocks may stay for the whole growing period. In some cases, however, they are consumed within a few weeks and have to be replaced. This will increase costs for labor and material.

The same concerns the supply of hay and straw in baskets or nets. The consumption of these materials is highly variable and the frequency of re-filling the baskets or nets is difficult to predict, should hay and straw be continuously available. Depending on type of enrichment extra labor costs for enrichment in a turkey pen with 4000 male birds ranged between 0.25 and 0.1 manpower-hours.

This resulted in total costs per bird for enrichment between 0.12 and 0.68 €: the lower costs were calculated for straw “on demand” presented in nets, and the highest costs for pecking blocks and hay given continuously in baskets.

Since enrichment is considered to positively influence the development of the birds, it has frequently been suggested that the higher costs for enrichment may be balanced by improved performance.

In the above-cited references, however, enrichment had no or only marginal effects on economically important criteria, such as growth rate, feed efficiency, mortality and meat quality.

Perches and raised platforms create additional space for the birds.

Positive effects on the economics would be achieved when this space would be considered as usable space and allow higher stocking density per m² floor area.

This procedure is, however, not accepted at present. To become economically viable, the higher costs have to be covered by higher market prices.

Table 1. *Costs of enrichment on the basis of preliminary experience. The costs (EUR) of various enrichment devices for turkeys have been estimated by Glawitz (2014 unpublished)*

Type of enrichment	Cost s/ unit	User for no. of crops	No. per 4000 toms	Costs per crop	Cost per bird
Pecking blocks	7,5	1	25	187,5	0,047
Hay baskets	60	10	8	48	0,012
Hay nets	15	3	10	15	0,004
Hay bales continuously	65	1	24	1560	0,39
Straw bales if required	25		10	25	0,006
Grit	5,2*	1	12	62,4	0,01

**Bag of 25 kg*

CONCLUSIONS

Enrichment of the environment has become an important argument in the discussion of broiler and turkey welfare. A multitude of different methods of enrichment have been developed and tested in experimental and commercial units. Enrichment can stimulate active behaviours, reduce fear and improve leg conditions. However, enrichment measures do not show positive effects on performance criteria. Introducing equipment and material for enrichment represents hygienic risks and additional costs. These costs cannot be balanced through savings in economically relevant criteria. The future will show to what extent retailers and consumers will be prepared to pay a higher price for broiler and turkey meat from enriched husbandry systems.

References. *Bailie, C. L., C. Ijichi and N. E. O'Connell (2018) Effects of stocking density and string provision on welfare-related measures in commercial broiler chickens in windowed houses. Poultry Science 97:1503–1510. DOI: 10.3382/ps/pey026.*

Balog, J. M., G. R. Bayyari, N. C. Rath, W. E. Huff and N. B.Anthony (1997) Effect of intermittent activity on broiler production parameters. Poult. Sci. 76: 6.

Baxter, M., C. L. Bailie and N. E. O'Connell (2018) Evaluation of a dustbathing substrate and straw bales as environmental enrichments in commercial broiler housing. Appl. Anim. Behav. Sci. 20: 78–85. DOI: 10.1016/j.applanim.2017.11.010.

Bench, C. J., M. A. Oryschak, D. R. Korver and E. Beltranena (2016) Behaviour, growth performance, foot pad quality, bone density, and carcass traits of broiler chickens reared with barrier perches and fed different dietary crude protein levels. Canadian Journal of Animal Science 97: 268–280. DOI: 10.1139/cjas-2015-0202.

Berk, Jutta and Gisela Hahn (2000) Aspects of animal behaviour and product quality of fattening turkeys influenced by modified husbandry. Archiv für Tierzucht 43 (3 SPEC. ISS) 189–195. http://www.scopus.com/inward/record.url?eid=2-s2.0-23644447912&partnerID=40&md5=2913309a676821db51f751a54e1480a0.

Berk, Jutta, Eva Stehle and T. Bartels (2017) Relationship between light quality, environmental enrichment and injurious pecking in turkeys. Xth European Symposium on Poultry Welfare. Ploufragan, France. https://www.openagrar.de/receive/openagrar_mods_00026665.

Bessei, W. (2018) Impact of animal welfare on worldwide poultry production. World's Poultry Science Journal 74: 211-224.

Bizeray, D., C. Leterrier, P. Constantin and J. M. Faure (2001) Sequential feeding with low lysine diet induces higher level of activity in meat-type chickens. Proc. 6th Europ. Symp. Poultry Welfare, Zollikofen, Switzerland, 173–176.

Bizeray, D. C. Leterrier, P. Constantin, M. Picard and J. M Faure. (2002) Sequential feeding can increase activity and improve gait score in meat-type chickens. Poult. Sci. 81: 1798–1806. http://www.scopus.com/inward/record.url?eid=2-s2.0-0036988280&partnerID=40&md5=b9f562d1becdf504798cbfbb6f78a5a7.

Bokkers, E.A.M. and P. Koene (2003) Behaviour of fast- and slow growing broilers to 12 weeks of age and the physical consequences. App. An. Behav. Sci. 81: 59–72.

DOI: 10.1016/S0168-1591(02)00251-4.

Buijs, S., L. J. Keeling, C. Vangestel, J. Baert, J. Vangeyte and F.A.M. Tuyttens (2010) Resting or hiding? Why broiler chickens stay near walls and how density affects this.

Applied Animal Behav. Sci. 124: 97–103. DOI: 10.1016/j.applanim.2010.02.007.

Cottin, E. (2004) Einfluss von angereicherter Haltungsumwelt und Herkunft auf Leistung, Verhalten, Gefiederzustand, Beinstellung, Lauffähigkeit und tibiale Dyschondroplasie bei männlichen Mastputen. Diss. Univ. Hannover.

Crowe, R. and J. M. Forbes(1999) Effects of 4 different environmental enrichment treatments on pecking behaviour in turkeys. Brit. Poultry Sci. 40: 11–12.

Davies, H. C. and C. A. Weeks (1995) Effects of age and leg weakness on perching behaviour of broilers. Brit. Poult. Sci. 36: 838.

Djukic, M., A. Harlander-Matauschek and W. Besse (2004) The effect of weight load on the legs on locomotor activity and resting behaviour of fast and slow growing chickens. Proc. 38th International Congress of the ISAE, Helsinki, Finland.

Gocsik, É.; Silvera, A. M.; Hansson, H.; Saatkamp, H. W.; Blokhuis, H. J. (2017): Exploring the economic potential of reducing broiler lameness. In: Br. Poult. Sci. 58 (4), S. 337–347. DOI: 10.1080/00071668.2017.1304530.

Jones, R. B. (2004) Environmental enrichment: the need for practical strategies to improve poultry welfare. In: Perry, G.C. (Ed.), Welfare of the laying hen. Papers from the 27th Poultry Science Symposium of the WP SA (UK Branch), Bristol, UK, July 2003. CABI Publ.

Jordan, D., I. Štuhec and W. Bessei (2011) Effect of whole wheat and feed pellets distribution in the litter on broilers' activity and performance. Arch.Geflugelkunde 75: 98–103. http://www.scopus.com/inward/record.url?eid=2-s2.0-80053058881&partnerID=40&md5=3c1ba5bfd3df614d9adc3f2f80a4ea8f.

Kaukonen, E., M. Norring, and A. Valros (2017) Perches and elevated platforms in commercial broiler farms: use and effect on walking ability, incidence of tibial dyschondroplasia and bone mineral content. Animal 11: 864–871. DOI: 10.1017/S1751731116002160.

Leterrier, C., C. Arnould, D. Bizeray, P. Constantinand J. M. Faure (2001) Environmental enrichment and leg problems in broiler chickens. Br.Poult.Sci. 42 (SUPPL. 1): 13-14.

Letzguß, Helga (2010) Einfluss von Beschäftigungs- und Strukturelementen auf das Verhalten und das Beinskelett konventionell gehaltener Mastputen. Diss. Univ. Hohenheim, Germany. http://opus.uni-hohenheim.de/volltexte/2010/477.

Malchow, J., J. Berk, B. Puppe and L.Schrader (2018) Perches or grids? What do rearing chickens differing in growth performance prefer for roosting? Poultry Science 8:1715. DOI: 10.3382/ps/pey320.

Malchow, Julia, Jutta Berk and L. Schrader (2018) Use of perches and grids during light and dark period by growing chickens differing in growth intensity. Proc. XVth European Poultry Conference: Dubrovnik, Croatia. https://www.openagrar.de/receive/openagrar_mods_00042482.

Martrenchar, A., D. Huonnic, J. P. Cotte, E. Boilletot and J. P. Morisse (1999) Influence of stocking density, artificial dusk and group size on the perching behaviour of broilers. Br. Poult. Sci. 41:125–130. DOI: 10.1080/713654921.

Mench, J.A., J. P. Garner and C. Falcone (2001) Behavioral activity and its effects on leg problems in broiler chickens. Proc. 6th Eur. Symp. Poult. Welfare. H. Oester and C. Wyss (ed.) World's Poultry Science Association, Zollikofen, Switzerland, 152–156.

Meyer, Meaghan M.; Johnson, Anna K.; Bobeck, Elizabeth A. (2019): A novel environmental enrichment device increased physical activity and walking distance in broilers. In: Poultry Science. DOI: 10.3382/ps/pez581.

Morris, T.R. (1967) Light requirement of the fowl. In: Carter, T. C. (Ed.) Environmental control in poultry production, Edinburgh-London.

Newberry, R.C. and D.M. Shackleton, (1997) Use of visual cover by domestic fowl. A Venetian blind effect? Animal Behaviour 54: 387–395. DOI: 10.1006/anbe.1996.0421.

Norring, M., E. Kaukonen and A.Valros (2016) The use of perches and platforms by broiler chickens. App. An. Behav. Sci. 184, S. 91–96. DOI: 10.1016/j.applanim.2016.07.012.

Olanrewaju, H.A., W.W. Miller, W.R. Maslin, S.D. Collier, J. L. Purswell and S.L. Branton (2018) Influence of light sources and photoperiod on growth performance, carcass characteristics, and health indices of broilers grown to heavy weights. Poult. Sci. 97:1109–1116. DOI: 10.3382/ps/pex426.

Onbaşilar, E.E., H. Erol, Z. Cantekin and Ü. Kaya (2007) Influence of intermittent lighting on broiler performance, incidence of tibial dyschondroplasia, tonic immobility, some blood parameters and antibody production. Asian-Aus.J.Anim.Sci. 20: 550–555. DOI: 10.5713/ajas.2007.550.

Pichova, K., J. Nordgreen, C. Leterrier L. Kostal and R.O. Moe (2016) The effects of food-related environmental complexity on litter directed behaviour, fear and exploration of novel stimuli in young broiler chickens. Appl.Anim.Behav.Sci. 174:83–89. DOI: 10.1016/j.applanim.2015.11.007.

Prescott, J.W. (1971) Early somatosensory deprivation as an ontogenetic process in the abnormal development of the brain and behavior. In: Medical Primatology. I.E. Goldsmith and J. Moor-Jankowski (Eds.) S. Karger, Basel, Switzerland.

Reiter, K. and W. Bessei (2009) Effect of locomotor activity on leg disorder in fattening chicken. In: Berl.Munch.Tierarztl.Wochenschr. 122: 264–270. DOI: 10.2376/0005-9366-122-264.

Riber, A.B., H.A. van de Weerd, I.C. de Jong and S. Steenfeldt (2017) Review of environmental enrichment for broiler chickens. Poultry Science, pex344-pex344. DOI: 10.3382/ps/pex344.

Rodriguez-Aurrekoetxea, A., E.H. Leone and I. Estevez (2014) Environmental complexity and use of space in slow growing free range chickens. App. An. Behav. Sci. 161:86–94. DOI: 10.1016/j.applanim.2014.09.014.

Rodriguez-Aurrekoetxea, A., E.H. Leone, and I. Estevez (2015) Effects of panels and perches on the behaviour of commercial slow-growing free-range meat chickens. App. An. Behav. Sci. 165:103–111. DOI: 10.1016/j.applanim.2015.02.004.

Scholtyssek, S. and M. Grashorn (1989) Laufböden in der Broilermast. Züchtungskunde 61: 152–163.

Schrader, L., S. Dippel and C. Nicol (2016) Do laying hens have a motivation to grasp while night time roosting? In: Proc. 50th Congress of the International Society for Applied Ethology. Past and Future: Standing on the Shoulders of Giants; July 2016, Edinburgh, UK. https://www.openagrar.de/receive/openagrar_mods_00020822.

Schwean-Lardner, K.; Fancher, B. I.; Gomis, S.; van Kessel, A.; Dalal, S.; Classen, H. L. (2013): Effect of day length on *cause of mortality, leg health, and ocular health in broilers. In: Poult. Sci. 92 (1), S. 1–11. DOI: 10.3382/ps.2011-01967.*

Sherwin, C.M., P.D. Lewis and G.C. Perry (1999) Effects of environmental enrichment, fluorescent and intermittent lighting on injurious pecking amongst male turkey poults. Brit. Poult. Sci. 40: 592–598. http://www.scopus.com/inward/record.url?eid=2-s2.0-0033255550&partnerID=40&md5=d8e6ed13d5505f2931160316029d7627.

Strassmeier, Petra (2007) Einfluss von Strukturelementen, Futterzusammensetzung und Witterung auf das Verhalten von gemischt gehaltenen BIG Six und Kelly Bronze Puten in der Auslaufhaltung. Diss. Tierärztl. Fak., LMU München, Germany.

Thomsen, M. G. (1989) Lysprogammet og foderstructurens inflydelse pa slagtekyllingers adfaersmonster. In: Statens Husdyrbrugsforsog. Meddelse Nr. 736, Kopenhagen, Denmark.

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