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Varying antibody responses of laying hens housed in an aviary system and in furnished cages

Unterschiede in der Antikörperantwort von Legehennen in Volierenhaltung und ausgestalteten Käfigen

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Summary

Antibody titers after vaccination against Infectious Bronchitis Virus (IBV), Newcastle Disease Virus (NDV) and after natural infection with *Campylobacter* were analyzed in five trials with Lohmann Silver laying hens kept in two different housing systems. In these studies it could be demonstrated that antibodies against IBV and *Campylobacter* were in 4 out of 5 respectively in 2 out of 5 trials significantly higher in hens housed in an aviary system compared to those kept in furnished cages. The opposite trend was observed for antibodies against NDV which were on average significantly higher in cages. The mean mortality rate was slightly higher in hens kept in the aviary system compared to the cage system.

Keywords: Infectious Bronchitis, Newcastle Disease, *Campylobacter*, antibody, mortality, housing system

Zusammenfassung

In fünf Durchgängen mit Hennen der Linie Lohmann Silver wurden die Antikörpertiter nach einer Impfung mit dem Infektiösen Bronchitis Virus (IBV) und dem Newcastle Disease Virus (NDV) sowie nach einer natürlichen Infektion mit *Campylobacter* ausgewertet. Die Haltung erfolgte in zwei verschiedenen Haltungssystemen, der Volierenhaltung und in ausgestalteten Käfigen. Die Studien zeigten, dass Antikörpertiter gegen IBV und *Campylobacter* in der Volierenhaltung in 4 von 5 bzw. in 2 von 5 Durchgängen signifikant höher ausfielen als bei Legehennen, die in ausgestalten Käfigen gehalten wurden. Ein gegenteiliger Trend wurde bei den NDV-Antikörpertitern beobachtet, die über alle Durchgänge gemittelt in ausgestalteten Käfigen signifikant höher lagen. Die Mortalität lag im Durchschnitt in der Volierenhaltung etwas höher als in der Käfighaltung.

Schlüsselwörter: Infektiöse Bronchitis, Newcastle Disease, *Campylobacter*, Antikörper, Mortalität, Haltungssytem

Introduction

Husbandry systems for laying hens in Germany have changed fundamentally in recent years. This is primarily due to the fact that conventional cages have been banned in Germany since 1 January 2010, two years earlier than in the entire EU. Since that time laying hens must be kept in small groups (furnished cages), in floor housing and free-range systems or in organic production systems. According to the EU Directive 1999/74/EC furnished cages must provide a space of at least 750 cm² area per hen of which 600 cm² shall have 45 cm free height above the total area. In addition the cage should have a nest with no direct contact to any wire mesh floor, a littered area for scratching and pecking, 15 cm of perches per hen, a feed trough of 12 cm per hen and claw-shortening devices. In Germany, the legal requirements for furnished cages are even stricter than in the EU Directive. The floor space must be at least 800 cm² including 90 cm² litter area per hen. In addition, a nest area of 90 cm² per hen should be provided, resulting in a total area of 890 cm² per hen. Perches have to be at

different heights and the minimum cage height has to be 50 cm and 60 cm at the feed troughs. Furthermore, the minimum total area of each cage must be 2.5 m² (Fröhlich et al. 2012). This enlarged furnished cage is called "small group housing". Deviating from the EU Directive 1999/74/EC, Germany decided to ban the small group housing system as well. There will be a transitional period till 2023 and 2025, respectively (Pressemitteilung, 2012), whereas in the other EU countries furnished cages are still permitted after the year 2012.

Changes in husbandry conditions have initiated intensive research such as studies on behavior, health and performance of laying hens in different housing systems. Leyendecker et al. (2005) and Scholz et al. (2008) showed that bone stability was enhanced in furnished cages and aviary housing systems compared to conventional cages and small group housing systems, respectively; egg shell stability proved to be higher in aviary systems than in cages (Scholz et al., 2008); positive effects on sole and toe pad health were observed in an aviary system (Rönchen et al., 2006) and the mortality rate in non-cage systems was higher than in cages (Weber et al., 2003; Weigl, 2007).

The antibody response of hens after vaccination can be influenced by many factors: the climate in pens, hygiene, the water quality, solar irradiation, polluted drinking troughs and the general condition of each hen and of the population in general (Litke, 1975). Fritsche et al. (1991) reported that even the dietary fat source has a significant effect on antibody production and lymphocyte proliferation of chickens. According to a study by El-Lethey et al. (2000), hens which were kept on litter showed a significantly higher immune response than hens without access to litter. Furthermore, according to Fitz (2007) even the litter material has an influence. He found significantly higher immunoglobulin Y concentrations in the egg yolk from hens kept on straw and straw pellets in comparison to those kept on wood shavings. Siegel (1985) mentioned that social or behavioral environments are also activators of stress responses in animals, and like physical stressors they are capable of reducing immune response. Similar results were reported by Martin (2005). She mentions that fear and stress are well known for reducing the immune response.

Only very few reports (Löliger et al., 1980; Gschwindt-Ensinger, 1986; Shini, 2003; Shimmura et al., 2010) have considered the antibody reaction in respect to poultry-keeping conditions. Therefore, the present study was conducted to investigate whether various housing systems affect the antibody response of laying hens.

Material and Methods

Housing conditions

The two housing systems examined were installed within separate rooms in one experimental building. The furnished cage system "Aviplus" (Big Dutchman, Vechta, Germany) consisted of a three-tier block of double-sided cages with solid sides and horizontal metal bars in the rear partitions and a sloping wire floor. Each compartment offered a height of 450 mm and was enriched with perches, a sand bath, nest box and claw shortening devices. Perches were incorporated in a parallel position to the length of each compartment with a length of 15 cm per hen. The group size in trials 1 to 3 was 10 hens per cage. In trials 4 and 5 the group sizes comprised 10 layers (bottom tier; floor space: 1,206 x 625 mm, 1 nest box per compartment), 20 layers (second tier; floor space: 2,412 x 625 mm, 2 nest boxes) and 30 hens (top tier floor space: 3,618 x 625 mm, 3 nest boxes). For each hen, 750 cm² floor space was available.

The aviary housing system (model "Natura", Big Dutchman) was equipped with a three-tier central block, a plastic slatted floor and a fully littered indoor floor space. The useable floor space was 271.36 m² including all tiers. On the two lower tiers the hens were fed from a trough with automatic chain feeders and water was supplied from nipple drinkers. Perches were installed in front of the second level and above the top level. Family nest boxes ("Colony-Nest", Big Dutchman) were attached to the walls opposite the central block. These could be accessed via footboards from the first and second tier of the system. Furthermore, hens had access to a sheltered outdoor area (~142 m²) littered with sand, wood shavings and straw. Both systems tested fully conformed to the EU legislative standards on keeping laying hens (EU Directive 1999/74/EC).

Breed, feeding and stocking

From April 2000 until October 2006 five trials with Lohmann Silver hens from Lohmann Tierzucht (LTZ, Cuxhaven, Germany) were housed in the research and teaching farm of the University of Veterinary Medicine Hannover. The two different housing systems were installed in one building and thus hens were kept under identical management conditions. Lohmann Silver hybrid used in the study is a predominantly white feathering layer for the production of uniform brown eggs with reduced egg weight. Its special advantage is the excellent feathering (LTZ Layer Management Guide) and a higher body weight compared to more common brown layer lines, such as Lohmann Brown or Lohmann Tradition.

All hens were reared together on the floor, thus ensuring fully identical rearing conditions. After vaccination against Marek´s disease in the hatchery birds were vaccinated against Newcastle disease (ND), avian infectious bronchitis (IB), infectious bursitis, encephalomylelitis, infectious laryngotracheitis, *Salmonella*, *Escherichia* (*E.*) *coli*, coccidiosis and egg-drop syndrome. The layers were moved to the laying unit at the age of 16 to18 weeks. For each trial slightly different numbers of hens were placed in the different housing systems. Table 1 shows the exact numbers for each of the five trials.

Ad libitum feeding with a standard layer diet was automatically provided three to four times a day and water was supplied ad libitum via nipple drinkers. The lighting period lasted 14 to 16 hours per day.

During the laying period the hens were generally revaccinated every three months against Newcastle disease and infectious bronchitis with the exception of trial 5. Figure 1 shows the vaccinations time points of each trial. Hens in trials 1 to 3 were vaccinated with the bivalent vaccine TAD® IB/ND vac Lyo from Lohmann Animal Health (LAH, Cuxhaven, Germany) consisting of IBV H120 and NDV LaSota. In trial 4 the vaccination was separated, with a time lag of six weeks between the two vaccinations with TAD® IB vac I Lyo and AviPro® ND LaSota (both from LAH). The hens in trial 5 were only revaccinated against IBV every three months with the vaccine TAD® IB vac I Lyo.

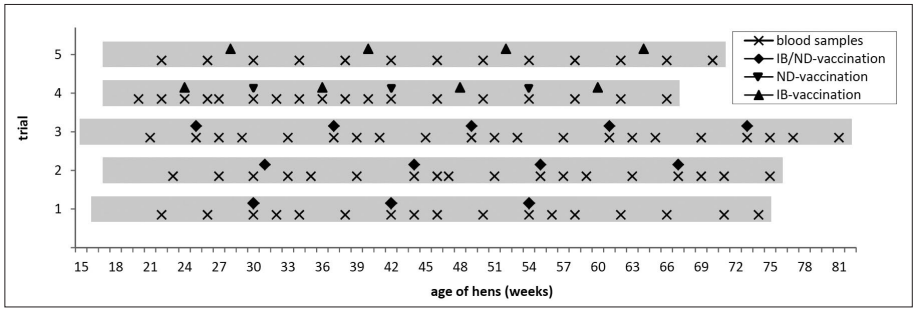

FIGURE 1: *Vaccinations and blood sampling time points for each trial.*

Blood samples

Blood samples from the brachial vein were taken for each time point from 25 randomly chosen hens from each housing system in order to investigate antibody titers against IBV, NDV and *Campylobacter*. The samples were taken monthly and additionally two weeks after each vaccination during the entire laying period (Fig. 1). They were centrifuged and the serum was stored at –70°C. All samples were examined with the same batch of ELISA kits after the end of each laying period to ensure an optimal comparability of the results. The ELISA kits for IBV (FlockCheck IBV) and NDV (FlockCheck NDV) were obtained from Idexx (Westbrook, USA). For detecting antibodies against *Campylobacter* an in-house ELISA, as previously described (Haas et al., 1999) was used. The relative level of antibody in the sample is determined by calculating the sample to positive ratio (S/P value).

Statistical methods

Statistical analysis was performed with the SAS system for Windows (Version 9.3, SAS Institute Inc., Cary, N.C., USA). The effects of the housing systems and weeks of age were estimated and tested separately for each of the five trials by means of a two-way-ANOVA (SAS-Procedure GLM). The housing systems were compared using the means of the means of the antibody titers of 25 hens at each time point. The interactions between the two main factors system and age were tested as well, separated according to trials, by means of a two-way ANOVA. The tests for normal distributions of the data within housing systems and weeks of age were conducted using the Shapiro-Wilk test (SAS-Procedure UNIVARIATE) for the residuals from the two-way-ANOVA linear model.

A three-way ANOVA to estimate and test the effect of the housing systems for all trials in one single analysis was not possible because the weeks of age examined were not consistent in the different trials. For this reason the trial was defined as a statistical unit with paired observations, in which each pair of values consists of the general mean for the aviary and the one for the cage. The comparisons of the means of these five means were carried out using the t-test for paired observations (One-sample t-test, SAS-Procedure MEANS). By this means, a summary of the five trials with regard to the aspect of the housing systems was still possible.

Statistical differences in the mortality rate were tested separately for each of the five trials with Pearson's Chi-Square test for homogeneity (SAS-Procedure FREQ). The means of the total mortality rate for all five trials were compared using the t-test for paired observations (One-sample t-test, SAS-Procedure MEANS). Different letters in the figures indicate statistically significant differences.

TABLE 1: *Overview of the different laying periods and numbers of hens in each trial*

Trial no	Laying period	Aviary	Furnished cages
1	04/2000–06/2001	n = 2110	n = 1560
2	07/2001–09/2002	n = 2004	n = 1533
3	09/2002–01/2004	n = 2318	n = 1560
4*	07/2004–07/2005	n = 1215	n = 839
5	09/2005–10/2006	n = 2500	n = 1560

*The hens of this trial were placed on half of the floor space to ensure the same stocking conditions

TABLE 2: *Numbers of blood samples for each trial*

Trial no	Aviary	Furnished Cages	Total
1	n = 425	n = 425	n = 850
2	n = 450	n = 450	n = 900
3	n = 525	n = 525	n = 1050
4	n = 270	n = 270	n = 540
5	n = 325	n = 325	n = 650

Results

Antibody response

In total, almost 4000 sera, 800 for each trial (Tab. 2), were tested for antibody titers against infectious bronchitis virus (IBV), Newcastle disease virus (NDV) and *Campylobacter* (S/P values). The hens were revaccinated against IBV und NDV quarterly during the entire laying period, except in trial 5 where hens were only revaccinated against IBV.

The average mean antibody titers against IBV (Fig. 2) and *Campylobacter* (Fig. 3) were slightly higher and partly statistically different in hens kept in the aviary system than in furnished cages. This tendency was observed in all trials except for IBV in trial 3 and for *Campylobacter* in trial 4.

Results for antibody titers against NDV (Fig. 4) showed an opposite trend: in 4 out of 5 trials, titers were significantly lower in hens in the aviary than in furnished cages (trial 1–3 $p = < 0.0001$, trial 4 $p = 0.0002$).

Mortality

The mortality rate in all five trials was slightly higher in hens kept in the aviary system than in furnished cages (Fig. 5). The increased mortality rate within the first two trials were significantly different compared to the other trials ($p = 0.0038$ and $p = < 0.0001$). In trial 1 the cause of the higher losses was predominantly due to inflammatory alterations of the sexual organs combined with an *E. coli* infection. The high mortality in the aviary system in trial 2 could be attributed to a self–limiting outbreak of histomoniasis during a ca. 4-week hot and humid summer period (August 2001) with temperatures up to 34°C. In the aviary system the mortality rate varied from 5.6%

in trial 5 to 21.7% in trial 2. In the furnished cages there was also a high deviation. The mortality rate varied from 4.9% in trial 5 to 20.1% in trial 4.

Discussion

According to our results, housing systems could have an influence on antibody production in laying hens.

The results demonstrate that antibody titers against IBV (Fig. 2) increased in 4 out of 5 trials significantly in hens kept in the aviary system which – besides other factors – concurrently provided the birds with more space for moving and interaction with numerous other individuals. Hörning et al. (2002) referred that the constant contact to various factors such as climate and sunlight have a positive effect on the immune system in laying hens kept in a free range system compared to hens kept in cages. A higher antibody level against IB vaccine in hens in the free-range system than in two different cage systems was observed by Shini (2003) who assumed that the antibody production was slightly affected by the housing systems. Gschwindt-Ensinger (1986) also found higher IBV antibody levels in hens housed in floor pens than those kept in cages.

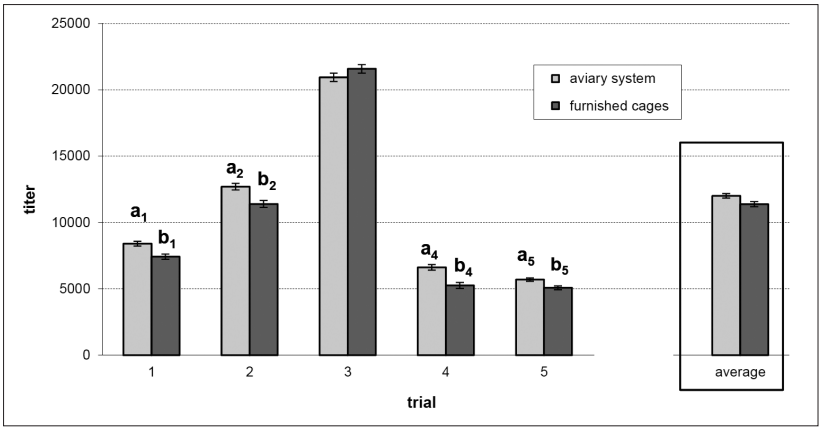

FIGURE 2: *IBV-antibody titers (mean) from hens kept in different housing systems, trial 1 to 5 (a, b = different letters indicate significant differences; standard errors are indicated by bars; statistical evaluation: trial 1 p = 0.0002, trial 2 p = < 0.0001, trial 3 p = 0.1177, trial 4 p = < 0.0001, trial 5 p = 0.0004, average p = 0.1191).*

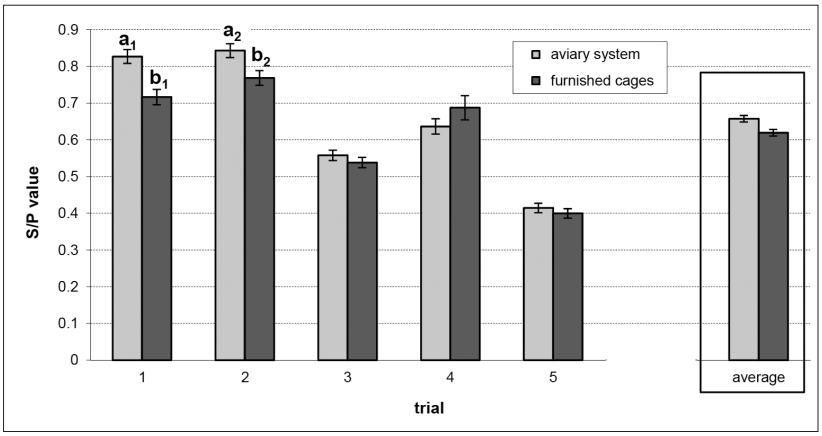

FIGURE 3: *Campylobacter-antibody titers (mean of S/P values) from hens kept in different housing systems, trial 1 to 5 (a, b = different letters indicate significant differences; standard errors are indicated by bars; statistical evaluation: trial 1 p = < 0.0001, trial 2 p = 0.0049, trial 3 p = 0.2528, trial 4 p = 0.0575, trial 5 p = 0.3587, average p = 0.2896).*

The S/P values against *Campylobacter* (Fig. 3) showed the same tendency like the IBV antibody titers. In 2 out of 5 trials, these were higher in hens kept in an aviary system than in furnished cages (p = < 0.0001, p = 0.0049). Heuer et al. (2001) reported similar results for broilers. They found higher infection rates with *Campylobacter* in organic broiler flocks (100%) compared to conventional (36.7%) and extensive indoor (49.2%) broiler flocks. *Campylobacter* is ubiquitous in the environment and generally colonizes the avian gut as a commensal organism (Glünder, 1995; Newell and Fearnley, 2003). The natural reservoirs of *Campylobacter* are commercial poultry and free-living birds (Shane, 1992). Therefore, it cannot be avoided that housing systems enabling close contact to the environment are infected with *Campylobacter* (Conraths et al., 2005). A further explanation of higher *Campylobacter* S/P values in the same trials in which simultaneously a higher mortality was observed in the aviary could be found in a higher rate of inflammation of the reproductive tract (trial 1) or an outbreak of histomoniasis (trial 2) since it is known that pathological alterations of sexual organs, an infection with salmonella or a parasitic disease such as coccidiosis can be accompanied by higher antibodies against *Campylobacter* (Glünder and Windhaus, 1998; Glünder et al., 1998).

In this study, antibody titers against NDV (Fig. 4) showed an opposite trend in comparison to the IBV and *Campylobacter* titers. In 4 out of 5 trials they were significantly higher in furnished cages than in the aviary system. In addition to the results for IBV and *Campylobacter* antibodies it could be secured statistically that NDV antibody titers were generally higher over all 5 trials in hens housed in cages (p = 0.0098). Löliger et al. (1980) also found that the antibody development against live ND vaccine virus is significantly higher in caged layers than in deep litter or free-range kept hens. In an experimental study, higher antibodies against human serum immunoglobulin G in hens kept in cages compared to free-range hens were reported by Erhard et al. (2000). In contrast, Shimmura et al. (2010) described that NDV antibody titer tended to be significantly lower in large furnished cages compared with a single-tiered aviary and a free range system. With regard to the NDV antibody titers, our findings as well as the results reported in the literature suggest that NDV antibody titers are higher in cages in contrast to housing systems which offer more space for moving and therefore enable contact to more companion chickens. This assumption is supported by Gschwindt-Ensinger (1986) who could demonstrate that antibodies against NDV and Gumboro-Virus increased when hens were kept over six generations in cages whereas vice versa antibodies against IBV and Reo-Virus rose when hens were kept in floor pens. Only few

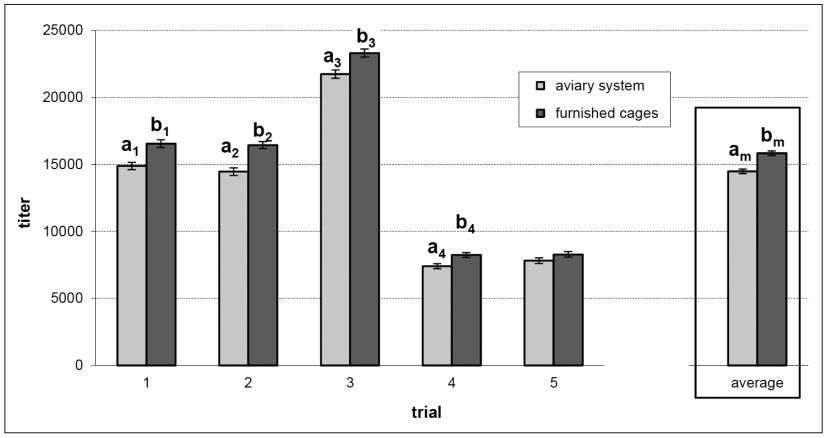

FIGURE 4: *NDV-antibody titers (mean) from hens kept in different housing systems, trial 1 to 5 (a, b = different letters indicate significant differences; standard errors are indicated by bars; statistical evaluation: trial 1 p = < 0.0001, trial 2 p = < 0.0001, trial 3 p = < 0.0001, trial 4 p = 0.0002, trial 5 p = 0.0713, average p = 0.0098).*

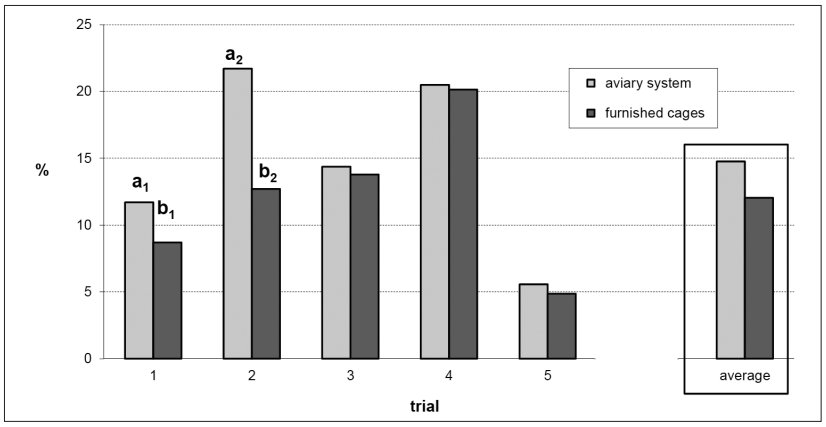

FIGURE 5: *Mortality from hens kept in different housing systems, trial 1 to 5 (a, b = different letters indicate significant differences; statistical evaluation: trial 1 p = 0.0038, trial 2 p = < 0.0001, trial 3 p = 0.6389, trial 4 p = 0.8673, trial 5 p = 0.3501, average p = 0.1721).*

reports (Weigl, 2007; Mammen, 2010) found no differences in antibody titers between housing systems.

The finding that antibody titers against IBV were higher in four of five trials in the aviary system, whereas the mean of antibody titers against NDV was higher in caged hens seems to be contradictory. However, similar opposite results are known to be provoked by other factors such as social stress which results in reduced resistance to some diseases such as *Mycoplasma gallisepticum*, Newcastle disease, hemorrhagic enteritis or Marek´s disease, whereas resistance to *E. coli* and *Staphylococcus aureus* is increased (Siegel, 1985).

Even though the hens in trial 5 were only revaccinated with IBV and not with NDV, the NDV antibody titers were still higher in hens housed in cages. Despite the hens in trials 1 to 3 were revaccinated against IB and ND with a bivalent-vaccine simultaneously and the revaccination in trial 4 was carried out separately with a monovalent NDV-vaccine followed by a monovalent IBV-vaccine with an intervening period of approximately six weeks (see Fig. 1) no influence of the different revaccination programs on the antibody response was seen in this study.

Concerning the high antibody titers in trial 3, a field infection with IBV and NDV cannot be ruled out but no clinical indications such as a reduced egg performance or poor egg quality were observed.

The genetic constitution seems to have no influence on the development of these antibody titers. In a previous study (Auerbach et al., 2006) with Lohmann Selected Leghorn, Tetra and Lohmann Tradition, antibody titers differed between housing systems but not between the breeds. Also van Loon et al. (2004) concluded from there results that, regardless of the genotype, the animals respond similarly to different environments. However, Lickteig (2006) and Rautenschlein et al. (2012) found differences in antibody responses among different genetic layer lines. Lickteig (2006) described higher concentrations of immunoglobulin Y in the egg yolk from Lohmann Brown hens compared to Lohmann Selected Leghorn. Data from Rautenschlein et al. (2012) indicate that differences between immunological parameters were mainly due to the genetic background of the laying hens.

On average, the mortality rate in the aviary system was marginally higher than in furnished cages with two exceptions. The difference in trial 1 can be explained by an increase of inflammatory alterations on the sexual organs combined with an *E. coli* infection. These losses were 3 times higher in the aviary system than in the furnished cages. The high mortality in the aviary system in trial 2 can be traced back to a self-limiting outbreak of histomoniasis, which accounts for losses of nearly 4%. All in all, nearly every trial shows a mortality rate over 10% for which we have no concrete evidence. It may be attributed to the quality of the management which can influence the mortality (Weizenbürger, 2005). Higher mortality rates in aviary systems are also reported by Petermann (2003) and Kreienbrock et al. (2004). Fossum et al. (2009) reported more necropsy of laying hens from flocks housed in litter-based and free-range systems in Sweden during the years 2001–2004, indicating a higher risk of increased mortality in these systems than in cages. Weigl (2007) found higher mortality rates in small group housing (4.8%) than in hens kept in an aviary system (2.9%). Tauson et al. (1999) reported varying mortality rates for different housing systems. While Lohmann Brown hens showed the highest mortality rate, 26.6% when housed in the aviary system, and 7.4% when housed in cages, the mortality rate in Lohmann Selected Leghorn was about 5.9% in the aviary system and 7.9% in cages. Furthermore, a higher risk of infections in alternative housing systems than in cages is reported to lead to a higher mortality rate.

The correlation of housing systems and behavior or health parameters such as laying performance, bone and egg shell stability, sole and toe pad health as well as mortality have already been described (Weber et al., 2003; Leyendecker et al., 2005; Rönchen et al., 2006, Weigl, 2007; Scholz et al., 2008). Our results suggest that the housing system can also influence antibody titers of

laying hens against certain antigens. However, the same environment may support higher antibody titers against some antigens and at the same time may lead to lower antibody titers against another antigen. This divers effect has to be further investigated.

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References

Auerbach MI., Weber RM, Beyerbach M, Glünder G (2006): Comparison of antibody titers in laying hens kept in an aviary system and in cages. World´s Poult Sci J, Suppl: 607–608.

Conraths FJ, Werner O, Methner U, Geue L, Schulze F, Hänel I, Sachse K, Hotzel H, Schubert E, Melzer F, Mettenleiter TC (2005): Konventionelle und alternative Haltungssysteme für Geflügel – Infektionsmedizinische Gesichtspunkte. Berl Münch Tierärztl Wochenschr 118: 186–204.

El-Lethey H, Aerni V, Jungi TW, Wechsler B (2000): Stress and feather pecking in laying hens in relation to housing conditions. Br Poult Sci 41: 22–28.

Erhard MH, Özpinar H, Bilal T, Abbas Y, Kutay C, Eseceli H, Stangassinger M (2000): The humoral immune response and the productivity of laying hens kept on the ground or in cages. Altern Lab Anim 28: 699–705.

Fitz B (2007): Vergleichende Untersuchungen zu Gesundheit, Leistung und Verhalten von Legehennen mit unterschiedlichen Einstreumaterialien in Volierenhaltung. München, LMU, veterinärmed Fak, Diss.

Fossum O, Jansson DS, Etterlin PE, Vågsholm I (2009): Causes of mortality in laying hens in different housing systems in 2001 to 2004. Acta Vet Scand 51:3.

Fritsche KL, Cassity NA, Huang S (1991): Effect of dietary fat source on antibody production and lymphocyte proliferation in chickens. Poult Sci 70 (3): 611–617.

Fröhlich EKF, Niebuhr K, Schrader L, Oester H (2012): What are alternative systems for poultry? In Sandilands V, Hocking PM (Hrsg.). Systems for Poultry – Health, Welfare and Productivity, Poultry Science Symposium, CAB International, Vol. 30: 1–22.

Glünder G (1995): Entwicklung humoraler präzipitierender Antikörper gegen *Campylobacter* spp. Beim Huhn. J Vet Med B 42: 89–99.

Glünder G, Hinz KH, Legutko P, Lange G, Haas B (1998): *Campylobacter*-Infektionen in Legehennenherden und Antikörperstatus. Referatesammlung 53. Fachgespräch, DVG Fachgruppe Geflügelkrankheiten, Hannover 1997: 151–165.

Glünder G, Windhaus H (1998): Investigations on *Campylobacter* in turkeys. Proceedings of the 1st International symposium on turkey diseases, Berlin, Germany 1998: 307–316.

Gschwindt-Ensinger B (1986): Der Einfluss unterschiedlicher Haltungssysteme auf einige stressrelevante physiologische Merkmale. Arch Geflügelk 50: 13–19.

Haas B, Hinz K-H, Glünder G (1999): Biotin-Streptavidin Enzyme-Linked Immunosorbent Assay for the Detection of Antibodies to *Campylobacter jejuni* and *C. coli* in Chickens. J Vet Med B 46: 163–171.

Heuer OE, Pedersen K, Andersen JS, Madsen M (2001): Prevalence and antimicrobial susceptibility of thermophilic *Campylobacter* in organic and conventional broiler flocks. Lett Appl Microbiol 33: 269–274.

Hörning B, Höfner M, Trei G, Fölsch D (2002): Auslaufhaltung von Legehennen. Arbeitspapier – Kuratorium für Technik und Bauwesen in der Landwirtschaft: Nr. 279, 65.

Kreienbrock L, Schäl J, Beyerbach M, Rohn K, Glaser S, Schneider B (2004): Epileg. Orientierende epidemiologische Untersuchung zum Leistungsniveau und Gesundheitsstatus in Legehennenhaltungen verschiedener Haltungssysteme. Abschlussbericht an das Niedersächsische Ministerium für den ländlichen Raum, Ernährung, Landwirtschaft und Verbraucherschutz, Institut für Biometrie, Epidemiologie und Informationsverarbeitung der Tierärztliche Hochschule Hannover, Bünteweg 2, 30559 Hannover.

Leyendecker M, Hamann H, Hartung J, Kamphues J, Neumann U, Sürie C, Distl O (2005): Keeping laying hens in furnished cages and an aviary housing system enhances their bone stability. Br Poult Sci 46: 536–544.

Lickteig E (2006): Vergleich der zwei Legehennenlinien Lohmann Selected Leghorn-Classic und Lohmann Brown-Classic unter den Bedingungen des Feldversuchs in Bezug auf Verhalten, Gesundheit und Leistung in Volierenhaltung. München, LMU, veterinärmed. Fak., Diss.

Litke OM (1975): Newcastle Disease: Faktoren, die eine Impfung über das Trinkwasser mit lentogenen Stämmen Hitchner B1 und La Sota beeinflussen können; Kontrolle des Impferfolges. Tierärztliche Hochschule Hannover, Diss.

Löliger H-CH, Hagen D, von dem Matthes S (1980): Tiergesundheit und klinische Parameter als Indiz für die Beurteilung tierschutzrelevanter Tatbestände in der Geflügelhaltung. Arch Geflügelk 44: 229–236.

Mammen S (2010): Untersuchungen zu den Auswirkungen verschiedener Haltungssysteme für Legehennen auf den Immunstatus der Tiere, unter Einbeziehung pathologisch-anatomischer, mikrobiologischer und hämatologischer Parameter. Tierärztliche Hochschule Hannover, Diss.

Martin G (2005): Das Nahrungserwerbsverhalten beim Haushuhn und die davon abgeleiteten Verhaltensstörungen Federpicken und Kannibalismus. In: Martin G, Sambraus HH, Steiger A (Hrsg.), Das Wohlergehen von Legehennen in Europa – Berichte, Analysen und Schlussfolgerungen Verlag Universität Kassel, Bd 28: 34–61.

Newell DG, Fearnley C (2003): Sources of *Campylobacter* colonization in broiler chickens. Appl Environ Microbiol 69: 4343–4351.

Petermann S (2003): Alternative Haltungssysteme – Erfahrungen aus der Praxis. DGS Magazin 35: 10–15.

Pressemitteilung (2012): Kleingruppenhaltung bei Legehennen: Niedersachsens Kompromiss-Initiative erfolgreich. Pressemitteilung vom 02.03.2012, Niedersächsisches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz und Landesentwicklung.

Rautenschlein S, Petersen H, Teske L, Sürie C, Haertle S, Haase C (2012): Comparison of immunological and health parameters of different layer hybrids housed in aviary and enriched colony systems. Proceedings of the 61st Western Poultry Disease Conference, AZ, USA, 1.–4.4.2012.

Rönchen S, Scholz B, Hamann H, Distel O (2006): Evaluation of plumage condition and foot pad health of laying hens housed in small group housing systems, furnished cages and an aviary system. In: Proceedings of the XII. European Poultry Conference, 10th–14th September 2006, Verona, Italy, 602.

Scholz B, Rönchen S, Hamann H, Sürie C, Neumann U, Kamphues J, Distl O (2008): Evaluation of bone strength, keel bone deformity and egg quality of laying hens housed in small group housing systems and furnished cages in comparison to an aviary housing system. Arch Tierz, Dummerstorf 51: 179–186.

Shane SM (1992): The significance of *Campylobacter jejuni* infection in poultry: a review. Avian Pathol 21: 189–213.

Shimmura T, Hirahara S, Azuma T, Suzuki T, Eguchi Y, Uetake K, Tanaka T (2010): Multi-factorial investigation of various housing systems for laying hens. Br Poult Sci 51: 31–42.

Shini S (2003): Physiological responses of laying hens to the alternative housing systems. Int J Poult Sci 2: 357–360.

Siegel HS (1985): Immunological responses as indicators of stress. World's Poult Sci J 41: 36–44.

Tauson R, Wahlström A, Abrahamsson P (1999): Effect of two floor housing systems and cages on health, production, and fear response in layers. J Appl Poult Res 8: 152–159.

Van Loon DPR, Hangalapura B, de Vries Reilingh G, Nieuwland MGB, Kemp B, Parmentier KH (2004): Effect of different housing systems on immune responses and body weight of chicken lines divergently selected for antibody responses to sheep red blood cells. Livestock Prod Sci 85 (2/3): 139–150.

Weber RM, Nogossek M, Sander I, Wandt B, Neumann U, Glünder G (2003): Untersuchungen zum Gesundheitsstatus von Legehennen in ausgestalteten Käfigen im Vergleich zu Tieren in konventioneller Käfig- und Bodenhaltung. Wien Tierärztl Mschr 90: 257–266.

Weigl B (2007): Gesundheitsstatus von Legehennen in Klein- und Großvolierenhaltung im Vergleich. München, LMU, veterinärmed Fak, Diss.

Weizenbürger D (2005): Evaluierung von Kleingruppenhaltung und ausgestalteten Käfigen hinsichtlich Gesundheitsstatus, Körperzustand und bestimmter ethologischer Parameter bei den Legelinien Lohmann Selected Leghorn und Lohmann Brown. Tierärztliche Hochschule Hannover, Diss.

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