Dust-bathing behavior of laying hens in enriched colony housing systems and an aviary system

H. Louton,*[,1] S. Bergmann,* S. Reese,† M. H. Erhard,* and E. Rauch*

*Department of Veterinary Sciences, Chair of Animal Welfare, Animal Behavior, Animal Hygiene and Animal Husbandry, Faculty of Veterinary Medicine, LMU Munich, Germany; and †Department of Veterinary Sciences, Chair of Anatomy, Histology and Embryology, Faculty of Veterinary Medicine, LMU Munich, Germany

ABSTRACT The dust-bathing behavior of Lohmann Selected Leghorn hens was compared in 4 enriched colony housing systems and in an aviary system. The enriched colony housing systems differed especially in the alignment and division of the functional areas dust bath, nest, and perches. Forty-eight-hour video recordings were performed at 3 time-points during the laying period, and focal animal sampling and behavior sampling methods were used to analyze the dust-bathing behavior. Focal animal data included the relative fractions of dust-bathing hens overall, of hens bathing in the dust-bath area, and of those bathing on the wire floor throughout the day. Behavior data included the number of dust-bathing bouts within a predefined time range, the duration of 1 bout, the number of and reasons for interruptions, and the number of and reasons for the termination of dust-bathing bouts. Results showed that the average duration of dust bathing varied between the 4 enriched colony housing systems compared with the aviary system. The duration of dust-bathing bouts was shorter than reported under natural conditions. A positive correlation between dust-bathing activity and size of the dust-bath area was observed. Frequently, dust baths were interrupted and terminated by disturbing influences such as pecking by other hens. This was especially observed in the enriched colony housing systems. In none of the observed systems, neither in the enriched colony housing nor in the aviary system, were all of the observed dust baths terminated "normally." Dust bathing behavior on the wire mesh rather than in the provided dust-bath area generally was observed at different frequencies in all enriched colony housing systems during all observation periods, but never in the aviary system. The size and design of the dust-bath area influenced the prevalence of dust-bathing behavior in that small and subdivided dust-bath areas reduced the number of dust-bathing bouts but increased the incidence of sham dust bathing on the wire mesh.

Key words: dust-bathing behavior, laying hen, sham dust bathing

2016 Poultry Science 95:1482–1491
http://dx.doi.org/10.3382/ps/pew109

INTRODUCTION

The enriched colony housing systems for laying hens (also known as enriched cages) were introduced in Germany as an alternative to conventional cages after these were forbidden by German law. The German Order on the Protection of Animals and the Keeping of Production Animals (2006), amended and published on August 22, 2006, and last changed on February 5, 2014, regulates the maintenance of livestock under animal protection aspects in Germany. The §13b of this order focuses on the requirements for keeping laying hens after the conventional cages were forbidden. However, due to procedural errors, this §13b, together with suggested measures for transitions, was declared unconstitutional by the Federal Constitutional Court of Germany in October 2010 (BVerfG, 2010). The §13b could nevertheless still be used as basis until March 31, 2012. Since then, keeping laying hens in enriched colony housing systems must follow general requirements of animal protection as described by the German Federal Ministry of Agriculture (BMELV, 2012).

In conventional cages, the available area per hen was 550 cm^2, and no litter (i.e., dust bath) area, perch, or nest was provided in this housing system (RL1999/74/EG, 1999). In enriched cages, on the other hand, the required area per hen by German law depends on the hens' weight, and it is 800 cm^2 or — if the weight exceeds 2 kg — 900 cm^2. Additionally, a litter area (900 cm^2/10 hens), a nest of 90 cm^2 area per hen, and perches of 15 cm length per hen must be offered. Furthermore, hens must be provided with

Received August 27, 2015.
Accepted February 17, 2016.

[1]Corresponding author: h.louton@lmu.de

litter material of a sufficient amount and with a loose structure that allows the hens to conduct their species-specific behaviors, such as pecking, scratching, and dust bathing (German Order on the Protection of Animals and the Keeping of Production Animals, 2006).

Dust bathing as a “high priority behavior” (EFSA, 2005) is conducted in sequential phases with various behavioral elements and functional purposes (van Rooijen, 2005). It is performed by many avian species and is considered a comfort behavior by many authors. Vestergaard et al. (1997) hypothesized that conditions that do not allow this behavior in hens may cause stress. Others reported a correlation between the size of the dust-bath area and dust-bathing activity, whereby a large size was preferred by the animals and led to increased dust-bathing activities (Appleby et al., 1993; Abrahamsson et al., 1996; Telle, 2011; Döring, 2012). Two essential functions of dust bathing are the removal of fatty agents and ectoparasites from the feathers and the improvement of the feather structure (Vestergaard, 1982; Martin and Mullens, 2012). The possibility to fulfill these and other functions depends among other factors on the available substrate (Van Liere et al., 1990).

The hens’ previous experience while they were raised before being moved to the laying system seems important for future acceptance of dust-bath materials (Vestergaard and Baranyiova, 1994; Petherick et al., 1995; Sanotra et al., 1995). Sham dust bathing on the wire mesh is seen primarily in hens housed in cages, even if an additional dust-bath area is provided (Vestergaard, 1987; Lindberg and Nicol, 1997; Olsson et al., 2002; EFSA, 2005). Sham dust bathing can be observed particularly often in an area close to the feeding trough (Lindberg and Nicol, 1997; Olsson et al., 2002; Hergt, 2007).

Under natural unrestricted conditions, hens perform a dust bath about every other day, and a complete dust bath takes 20 to 30 min (Vestergaard, 1982; Engelmann, 1984; van Liere et al., 1990). Hens prefer substrate consisting of small, fine-grained particles (Van Liere et al., 1990; Olsson and Keeling, 2005). Although the reports on the duration of dust-bathing bouts under commercial conditions differ in numbers, altogether considerably shorter durations were reported for laying hens in enriched cages, with bouts lasting 5 to 10 min (Appleby et al., 1993; Hergt, 2007), 8 to 9 min (Sewerin, 2002), or 4 min (Telle, 2011). In conventional cages, several particularly short dust-bathing bouts were observed, each of them lasting 10 s (Appleby et al., 1993). If a dust bath is short (up to 5 min), the hens can accomplish only the first of the dust-bathing phases described by van Rooijen (2005). In this phase, through flapping of the wings, the substrate is distributed between the feathers (Van Liere et al., 1990).

Feed often is used as the required litter material in enriched colony housing systems. The litter material usually is supplied several times per day in the dust-bath areas, which typically consist of Astroturf® mats. Nevertheless, some authors claim that feed is not a suitable material for dust bathing, because hens prefer material with low lipid concentrations, and dust bathing in food particles raises the lipid concentration on feathers (Scholz et al., 2011, 2014). Alvino et al. (2013) emphasized that data on the influence of Astroturf® mats on the dust-bathing behavior of hens raised in enriched cages are still relatively rare and conflicting. The authors compared dust-bathing behavior of laying hens on dust-bath mats with and without feed with the behavior shown in a dust box filled with sand. They concluded that Astroturf® with or without the provision of feed is not an adequate dust-bath substrate compared with sand (Alvino et al., 2013).

Reasons why hens terminate their dust bath may vary. The termination can often be caused by aggressive and other distracting behavior of conspecifics. Painful contact to the wire mesh or lack of positive feedback could be further reasons (Vestergaard, 1987; Hergt, 2007; Telle, 2011). No complete dust-bathing bouts could be observed in a study on dust-bathing behavior of hens in enriched cages (De Jong et al., 2006).

This observational study examined the dust-bathing behavior of laying hens in terms of the use of various areas in the cage and the frequency, duration, and quality of dust-bathing behavior, including interruptions and premature terminations, in 4 enriched colony housing systems and in 1 aviary system. The results were compared with those from available literature. To identify measures that could support this comfort behavior, we examined if the size and design of dust-bath areas influence dust-bathing behavior and potentially affect the welfare of caged laying hens.

ANIMALS, MATERIALS, AND METHODS

This study was conducted in the context of a joint research project to improve and optimize the enriched colony housing systems for laying hens in Germany. Five scientific institutions participated in this combined project, which ran from 2008 to 2011. Laying hens of 3 subsequent laying periods of 12 months each were the basis of the research. The results presented here originate from the third laying period (October 2010 to October 2011).

Non-beak-trimmed Lohmann Selected Leghorn hens were transferred to 4 enriched colony housing systems of 3 manufacturers (systems A, B, C, and D) and to 1 aviary system (system E) at the age of 17 wk and 6 d. Differences between the systems consisted particularly in the alignment and division of the 3 functional areas dust bath, perches, and nest (Figure 1). The hens were fed with conventional layer feed of 3 phases (Korngold LAM 41®, Korngold LAM 40®, and Korngold LAM 38®; BayWa AG, Bockhorn, Germany) during the laying period. Exact doses of components are given in Table 1. Seashell grit (OSTREA®, Van der Endt-Louwerse B.V., Yerseke, Netherlands) was fed at about 5 g per hen 3 times per wk from the 30th wk of life onward.

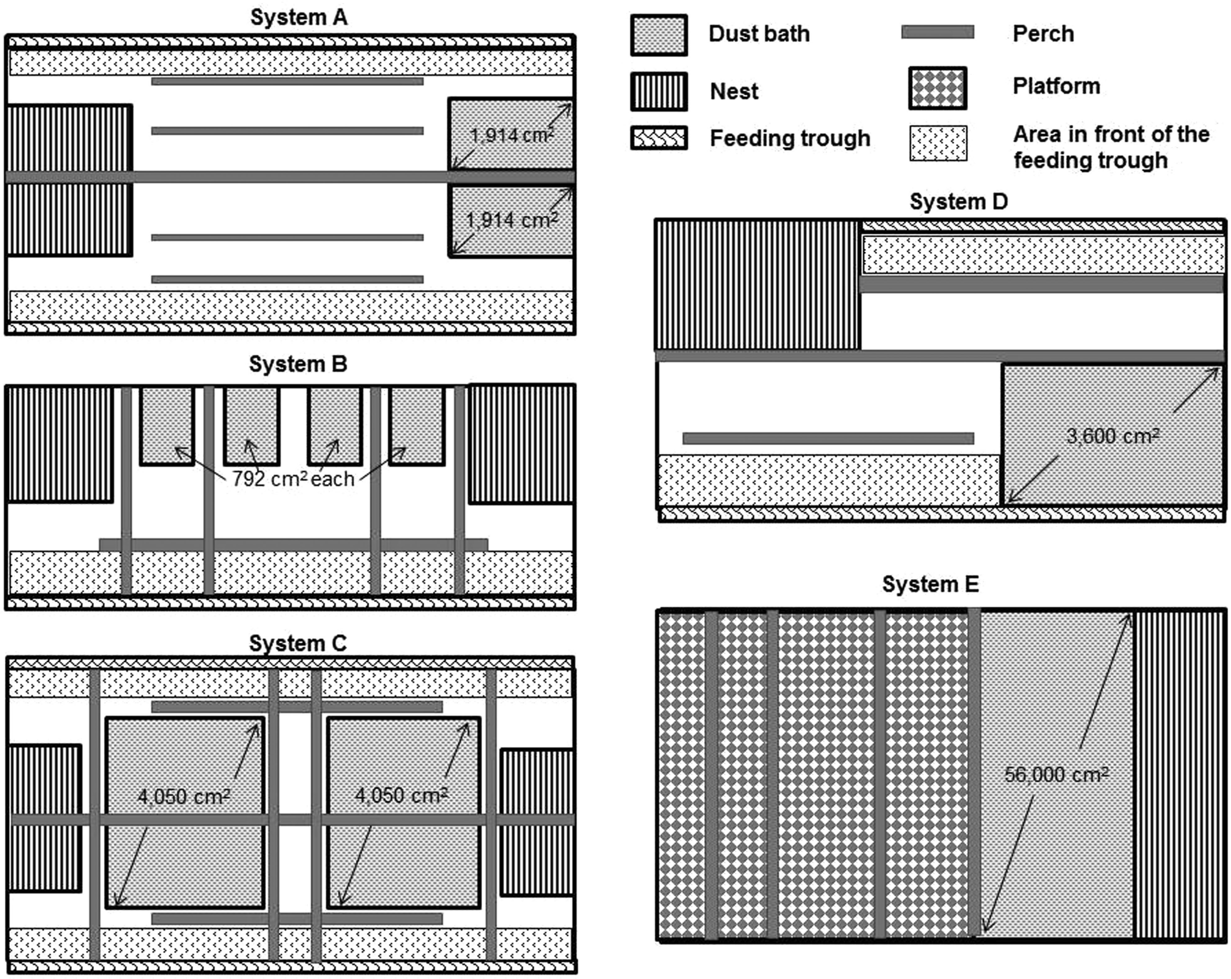

Figure 1. Presentation of the functional areas dust bath, nest, and perch and the defined "area in front of the feeding trough" in the 4 observed enriched colony housing systems, systems A to D, and the aviary system, system E. Measurements indicate the size of the dust-bath area.

Table 1. Phases and names of the used feed with details on the contents (crude protein, energy, methionine, calcium, and phosphor) in relation to the age of the laying hens.

Phase	Age of hens (wk)	Name of feed	Crude protein (%)	Energy (MJ)	Methionine (%)	Calcium (%)	Phosphorus (%)
1	18–47	Korngold LAM 41®	18.00	11.60	0.41	3.80	0.55
2	48–63	Korngold LAM 40®	17.50	11.40	0.40	3.80	0.50
3	64–70	Korngold LAM 38®	17.00	11.40	0.38	4.10	0.50

System A had 2 dust bath litter areas per section with a size of 1,914 cm^2 each, and an animal group size of 40 hens (stocking density: 800 cm^2/hen). System B had 4 dust-bath litter areas per section with a size of 792 cm^2 each, and a group size of 33 hens (stocking density: 800 cm^2/hen). System C had 2 dust-bath litter areas per section with a size of 4,050 cm^2 each, and a group size of 50 hens (stocking density: 880 cm^2/hen). System D had 1 dust-bath litter area per section with a size of 3,600 cm^2, and a group size of 40 hens (stocking density: 800 cm^2/hen). The aviary system E had 1 dust-bath litter area of 56,000 cm^2, and a group size of 100 hens (stocking density: 1,120 cm^2/hen). The dust-bath mats in the enriched colony housing systems were filled automatically several times per day with the usual commercially available litter substrate (layers feed) at approximately 50 g per mat. In all systems, only artificial lighting was used with a 16 h daylight period.

Video recordings of 48 h duration each were performed at 3 time-points over the laying period in order to assess the behavior of the laying hens, with focus on the dust-bathing behavior. Dust bathing behavior was defined as a behavior in which a hen shows vertical wing shakes in a lying position. Infrared cameras

(VTC-E220IRP, Santech, Ahrensburg, Germany) were used and installed so that the use of perches, dust-bath area, and wire mesh during the daytime could be observed. The observation periods (**OPs**) were at 24 to 25 wk of the hens' age (OP 1), 47 to 48 wk (OP 2), and 63 to 64 wk (OP 3). Observations recorded during the daytime were analyzed following the principles described by Martin and Bateson (2007). Results from statistical analyses were considered significant if the P-value was equal to or below 0.05.

Scan Sampling, Assessment of the General Use of the Dust Bath Area

Thirty minutes after the beginning of the daylight period, a scan sampling was used with an hourly interval to assess the location of the hens in the functional areas of the housing system (14 scans per OP). The number of hens in the dust-bath area in relation to the total number of hens in the pen was counted as an indicator of the use of the dust-bath area in the 5 housing systems. To evaluate the general use of the dust-bath area, this indicator (as an average of the 14 scans) was analyzed with a chi-square test (4-field test, Excel Tool as download from ACOMED Statistics, Leipzig, Germany). In addition, the correlation between the size of the dust-bath area in the enriched colony housing systems and the fraction of hens in this area was assessed by a Pearson correlation test.

Behavior Sampling, Assessment of the Location of Dust Bathing Activities

The fraction of dust-bathing hens in the provided dust-bath area or on the wire mesh was counted hourly beginning 30 min after the onset of the daylight period. The area "wire mesh" was separated into "wire mesh near the perches" or "wire mesh at the feeding trough." In the assumed main period of dust bathing, from 9:30 AM to 2:30 PM, the behavior was sampled at 20 min intervals.

To compare the locations where dust-bathing behavior was shown in the systems, the total number of hens observed in the 2 areas "dust bath" or "wire mesh" (as an average of the daytime) in relation to the total number of hens in the pens of the systems was used. The statistical significance was analyzed with a chi-square test (4-field test, Excel Tool as download from ACOMED Statistics, Leipzig, Germany). A Pearson correlation test was used to evaluate the correlation between the size of the dust-bath area and the numbers of dust-bathing hens overall, hens bathing in the dust-bath area, or those sham bathing on the wire mesh in the enriched colony housing systems.

Based on the data from the individual scans during the daytime (24 scans per day, average of a 48 h OP), the area under the curve was calculated for the fractions of hens dust bathing in the areas "dust bath," "wire mesh near the perches," and "wire mesh at the feeding trough." A Fisher–Pitman test (exact test for 2 independent random samples) was used to determine whether the hens in each system dust bathed more or less frequently in the area between the feeding trough and the nearest perch (Figure 1) compared with the other areas (e.g., between perches) as reported by other authors (Lindberg and Nicol, 1997).

Focal Sampling, Assessment of the Quantity and Duration of Dust Bathing Bouts

The dust-bathing behavior during daytime was observed on the basis of a continuous recording during a defined time slot once a day (lasting 60 min), immediately after the first application of feed onto the dust-bath area. During this time slot, we recorded how many hens and how long they dust bathed, why and how often dust baths were interrupted, and why dust baths were terminated. In addition, the general quantity of dust-bathing bouts during a defined observation and daytime time period was evaluated by setting the average number of dust-bathing bouts in all areas (within 48 h) in relation to the number of hens in the pen. The statistical analysis was performed by using a chi-square test to compare the housing systems by multiple comparisons of each enriched colony housing system (A to D) with the aviary system E (4-field test, Excel Tool as download from ACOMED Statistics, Leipzig, Germany). To evaluate the correlation between the size of the dust-bath area and the average number of dust-bathing bouts shown in the enriched colony housing systems, a Pearson correlation test was used.

In addition, the chi-square test was used to evaluate statistical significance of differences between the systems in respect to interrupted and early-terminated dust-bathing bouts. The average number of interruptions per dust-bathing bout was calculated by dividing the total number of interruptions by the total number of dust-bathing bouts performed during 1 time slot in 1 system. This includes multiply-interrupted dust-bathing bouts. An interruption was defined as a time period, lasting less than 2 min, between 2 dust baths of 1 hen in which the hen was in a standing position and not showing vertical wing shakes. The end (termination) or interruption of a dust-bathing bout that occurred without any noticeable disruption, e.g., the hen standing up and leaving the site, was defined as "normal." Other defined causes for terminations or interruptions were "being pecked at by another hen," "being pushed out of the dust-bath area by another hen," "being obviously startled," "dust-bathing hen dominating another hen," or "other reasons." Because of technical reasons, a sound analysis to identify terminations or interruptions due to noise was not possible.

To calculate the average dust-bathing duration, individually observed dust-bathing bouts within the observation and daytime period were considered, an average was calculated, and the shortest and longest dust-bathing bouts evaluated. The statistical analysis of differences in dust-bathing duration was performed with a Mann–Whitney U test.

RESULTS

Scan Sampling, Assessment of the General Use of the Dust Bath Area

As presented in Table 2, more hens were observed in the dust-bath area in the aviary system (system E) than in the enriched colony housing systems (systems A to D) during all OPs ($P = 0.05$, chi-square test, multiple comparisons of each system A to D with system E). In contrast to system E, where on average 27.6% of the hens were seen in the dust-bath area during the daytime of the OP 1, on average 12.8% of the hens were seen in the dust-bath area in systems A to D (ranging from 8.2% in system A to 17.6% in system D). During the OPs 2 and 3, on average 35.7 and 34.4%, respectively, of the hens in system E and on average 12.1 and 10.9%, respectively, of the hens in systems A to D were seen in the dust-bath area.

During the OP 1, more hens used the dust-bath area in system D (17.6%) than in systems A (8.2%) and B (9.5%) ($P = 0.05$, chi-square test). A positive correlation was observed between the size of the provided individual dust-bath mats in the enriched colony housing systems and the average number of hens in the dust-bath area (Pearson correlation, $r = 0.739$, $P = 0.006$).

Behavior Sampling, Assessment of the Location of Dust Bathing Activities

Table 3 lists the total fraction of dust-bathing hens during the daytime and the fractions subdivided into hens that were dust bathing in the provided dust-bath area and those that were sham dust bathing on the wire floor. This behavior was assessed as a sum of 24 behavior samplings.

During the OP 1, more hens were observed dust bathing during daytime in systems A, C, and D than in systems B and E ($P = 0.05$, chi-square test). During the OP 2, more dust-bathing hens were observed in system C than in systems A, B, and D ($P = 0.05$, chi-square test). Furthermore, more hens were observed dust bathing during daytime in systems A, C, D, and E than in system B, which was equipped with smaller and subdivided dust baths ($P = 0.05$, chi-square test). During the OP 3, more dust-bathing hens were observed in system D than in systems A, B, and E ($P = 0.05$, chi-square test). A positive correlation was observed between the size of the individual dust-bathing mats in the enriched colony housing systems and the total fraction of dust-bathing hens during the daytime (Pearson correlation, $r = 0.918$, $P = 0.01$).

Comparing the areas where the hens showed dust-bathing behavior, we found the following differences: Most dust-bathing bouts in systems A and B were observed on the wire mesh rather than in the provided dust-bath area during all 3 OPs (System A: OP 1: 85.2%, OP 2: 56.1%, OP 3: 97.7% of all dust-bathing bouts on the wire mesh; System B: OP 1: 97.5%, OP

Table 2. Comparison of systems A to E in terms of the hens' use of dust-bath areas during the daytime and over 3 observation periods (OP) in percent and absolute numbers (in parentheses) based on 14 scan samplings during a 48 h observation period. Presentation of 95% confidence intervals (CI) of the mean values with lowest (CI low) and highest value (CI high).

System A			System B			System C			System D			System E		
Number of sections observed: 4			Number of sections observed: 4			Number of sections observed: 3			Number of sections observed: 6 (resp. 3)			Number of sections observed: 2		
Fraction of hens in the dust-bath area	95% CI low	95% CI high	Fraction of hens in the dust-bath area	95% CI low	95% CI high	Fraction of hens in the dust-bath area	95% CI low	95% CI high	Fraction of hens in the dust-bath area	95% CI low	95% CI high	Fraction of hens in the dust-bath area	95% CI low	95% CI high
OP 1 (hens at 24–25 wk of age)														
8.2% (13.1/160)	7.7	8.7	9.5% (12.5/132)	8.9	10.1	15.9% (23.9/150)	15.1	16.7	17.6% (42.2/240)	17.0	18.1	27.6% (55.2/200)	25.9	29.3
Average in the enriched cage housing systems (A–D): 12.78%														
OP 2 (hens at 47–48 wk of age)														
8.7% (13.7/157)	8.2	9.2	11.7% (15.2/130)	11.0	12.4	13.8% (20.4/148)	13.1	14.6	14.0% (29.3/209)	13.3	14.6	35.7% (69.6/195)	33.3	38.2
Average in the enriched cage housing systems (A–D): 12.05%														
OP 3 (hens at 63–64 wk of age)														
7.3% (11.3/154)	6.8	7.8	9.8% (12.4/126)	9.2	10.5	13.2% (19.4/147)	12.5	13.9	13.2% (14.1/107)	12.3	14.1	34.4% (65.7/191)	31.9	36.9
Average in the enriched cage housing systems (A–D): 10.89%														

Table 3. Comparison of systems A to E in terms of the total fraction of hens showing dust-bathing behavior overall and separated into dust bathing in the provided dust-bath area or on the wire mesh during the daytime and over 3 observation periods (OP) in percent and absolute numbers (in parentheses) based on 24 behavior samplings during a 48 h observation period. Presentation of standard deviation (SD) and the standard error of the estimate of the mean value (SEM).

Dust bathing	System A			System B			System C			System D			System E		
	Observed hens	SD	SEM	Observed hens	SD	SEM	Observed hens	SD	SEM	Observed hens	SD	SEM	Observed hens	SD	SEM
OP 1 (hens at 24–25 wk of age)															
Overall	56.9% (91.0/160)	2.6	0.26	29.9% (39.5/132)	1.7	0.18	76.3% (114.5/150)	2.4	0.29	65.4% (157.0/240)	2.5	0.21	39.8% (79.5/200)	1.9	0.27
Dust bath area	8.4% (13.5/160)	0.7	0.07	0.8% (1.0/132)	0.2	0.02	65.0% (97.5/150)	2.2	0.26	44.2% (106.0/240)	2.0	0.17	39.8% (79.5/200)	1.9	0.27
Wire mesh	48.4% (77.5/160)	2.2	0.23	29.2% (38.5/132)	1.7	0.18	11.3% (17.0/150)	0.8	0.09	21.3% (51.0/240)	1.2	0.10	0.0% (0/200)	0	0
OP 2 (hens at 47–48 wk of age)															
Overall	60.2% (94.5/157)	2.1	0.21	33.9% (44.0/130)	2.1	0.21	78.4% (116.0/148)	2.8	0.33	62.0% (129.5/209)	2.7	0.22	69.2% (135.0/195)	2.2	0.32
Dust bath area	26.4% (41.5/157)	1.3	0.14	2.3% (3.0/130)	0.4	0.04	67.2% (99.5/148)	2.3	0.27	42.1% (88.0/209)	2.0	0.16	69.2% (135.0/195)	2.2	0.32
Wire mesh	33.8% (53.0/157)	1.5	0.16	31.5% (41.0/130)	2.0	0.21	11.2% (16.5/148)	0.9	0.10	19.9% (41.5/209)	1.3	0.11	0.0% (0/195)	0	0
OP 3 (hens at 63–64 wk of age)															
Overall	60.4% (93.0/154)	2.1	0.21	29.4% (37.0/126)	1.6	0.16	69.4% (102.0/147)	2.4	0.28	78.0% (83.5/107)	3.2	0.38	66.2% (126.5/191)	1.9	0.27
Dust bath area	19.5% (30.0/154)	1.0	0.10	2.0% (2.5/126)	0.4	0.04	59.2% (87.0/147)	2.1	0.24	50.9% (54.5/107)	2.0	0.24	66.2% (126.5/191)	1.9	0.27
Wire mesh	40.9% (63.0/154)	1.7	0.22	27.4% (34.5/126)	1.5	0.16	10.2% (15.0/147)	0.8	0.09	27.1% (29.0/107)	1.8	0.21	0.0% (0/191)	0	0

2: 93.2%, OP 3: 93.2% of all dust-bathing bouts on the wire mesh). This difference was significant ($P = 0.05$, chi-square test) during all OPs in system B and during the OPs 1 and 3 in system A. In systems C and D, more hens were seen dust bathing in the provided dust-bath area than on the wire mesh during all OPs ($P = 0.05$, chi-square test; Table 3). The correlation between the fraction of hens dust bathing in the provided area and the size of the individual dust-bath mats was positive (Pearson correlation, $r = 0.971$, $P = 0.01$), whereas the correlation between the fraction of hens dust bathing on the wire mesh and the size of the individual dust-bath mats was negative (Pearson correlation, $r = -0.693$, $P = 0.013$), indicating more hens were dust bathing on the wire mesh when smaller dust-bath areas were provided.

In the aviary system (system E), dust bathing on the wire mesh was never observed during any of the OPs, and the hens always dust bathed in the provided dust-bath area. Systems C and D were enriched colony housing systems with larger and connected dust-bath mats compared with systems A and B. The aviary system E had the largest dust-bath area.

Regarding the location of dust-bathing activities on the wire mesh, we found that in systems A and B during all OPs, and in system D during the OPs 2 and 3, dust bathing on the wire mesh occurred more often in the area between the feeding trough and the nearest perch (Figure 1) than on the wire mesh between the perches ($P = 0.01$, Fisher–Pitman test).

Focal Sampling, Assessment of the Quantity and Duration of Dust Bathing Bouts

The smallest number of dust-bathing bouts per hen during the analyzed 60 min time slot of the continuous recording was observed in system B during the OPs 1 and 2 ($P = 0.05$, chi-square test; Table 4). Comparing the relative fractions of dust-bathing hens, we found that the hens in system C showed dust-bathing behavior most frequently during all OPs (Table 4). During the OP 1, more dust-bathing bouts were noted in system C than in any other system ($P = 0.05$, chi-square test); during the OP 2, this was the case compared with systems A and B, and during the OP 3, more dust-bathing bouts were observed in systems C and D compared with systems A, B, and E ($P = 0.05$, chi-square test; Table 4). A positive correlation was observed between the size of the individual dust-bath mats in the enriched colony housing systems and the number of dust-bathing bouts during a 60 min time slot of continuous recording (Pearson correlation, $r = 0.941$, $P = 0.01$).

The average duration of a dust-bathing bout varied not only between the 5 systems but also within a

Table 4. Comparison of systems A to E in terms of the average number of dust-bathing bouts. Average relative fraction of dust-bathing bouts that ended "normally," reason for dust-bath termination as a mean value of the 3 observation periods, average relative fraction of interruptions of a bout, and reason for dust-bathing interruption as a mean value of the 3 observation periods. OP = Observation period; Ø = average; SD = standard deviation; MV = mean value, n.a. = not assessed, Reason 0 = without disruption, Reason 1 = being pecked at by another hen, Reason 2 = being pushed from the dust-bath area by another hen, Reason 3 = being obviously startled, Reason 4 = dust-bathing hen dominating another hen, Reason 5 = other reasons.

		System A		System B		System C		System D		System E	
Number of sections observed		4		4		3		6		2	
Number of hens per section		40		33		50		40		100	
	OP	ø	SD	ø	SD	ø	SD	ø	SD	ø	SD
Average number of dust-bathing bouts/exact number of hens	1	14.5/160	1.57	2.5/132	1.45	31.5/150	12.17	28.0/240	6.74	17.5/200	1.06
	2	12.0/157	3.01	2.0/130	1.24	38.0/148	6.62	39.0/209	4.97	23.0/195	5.55
	3	13.5/154	4.82	4.5/126	4.26	29.5/147	8.81	20.0/107	2.64	12.0/191	1.62
Average relative fraction of bouts that ended normally (undisrupted)	1	48.3%	n.a.	60.0%	n.a.	44.4%	n.a.	50.0%	n.a.	82.9%	n.a.
	2	54.2%	n.a.	25.0%	n.a.	67.1%	n.a.	35.9%	n.a.	91.3%	n.a.
	3	51.9%	n.a.	88.9%	n.a.	59.3%	n.a.	38.5%	n.a.	87.5%	n.a.
Reason for termination 0	MV 1–3	51.2%	n.a.	66.7%	n.a.	57.6%	n.a.	41.0%	n.a.	87.6%	n.a.
Reason for termination 1		16.2%	n.a.	11.1%	n.a.	10.6%	n.a.	26.0%	n.a.	2.9%	n.a.
Reason for termination 2		17.5%	n.a.	11.1%	n.a.	13.6%	n.a.	20.8%	n.a.	0%	n.a.
Reason for termination 3		3.8%	n.a.	11.1%	n.a.	4.5%	n.a.	1.2%	n.a.	1.9%	n.a.
Reason for termination 4		1.2%	n.a.	0%	n.a.	3.5%	n.a.	4.0%	n.a.	4.8%	n.a.
Reason for termination 5		10.0%	n.a.	0%	n.a.	10.1%	n.a.	6.9%	n.a.	2.9%	n.a.
Average relative fraction of interruptions of bouts	1	42.5%	45.1	0.0%	0.0	57.0%	65.9	44.0%	43.6	13.5%	10.6
	2	78.3%	73.9	0.0%	0.0	48.0%	18.1	77.3%	30.6	8.0%	11.3
	3	18.5%	12.9	12.5%	25.0	65.7%	14.0	55.3%	54.5	0%	0
Reason for interruption 0	MV 1–3	39.5%	n.a.	100%	n.a.	38.1%	n.a.	28.2%	n.a.	70.0%	n.a.
Reason for interruption 1		21.1%	n.a.	0%	n.a.	14.3%	n.a.	32.7%	n.a.	10.0%	n.a.
Reason for interruption 2		7.9%	n.a.	0%	n.a.	9.5%	n.a.	20.9%	n.a.	0%	n.a.
Reason for interruption 3		0%	n.a.	0%	n.a.	1.0%	n.a.	0.9%	n.a.	10.0%	n.a.
Reason for interruption 4		13.2%	n.a.	0%	n.a.	17.1%	n.a.	10.0%	n.a.	0%	n.a.
Reason for interruption 5		18.4%	n.a.	0%	n.a.	20.0%	n.a.	7.3%	n.a.	10.0%	n.a.

system over the course of the 3 OPs (Table 5). Very short and very long dust-bathing durations could be observed in all systems. The shortest dust-bathing duration was 0.07 min (system C) and the longest was 44.03 min (system D). Table 5 lists the shortest, longest, and average durations of the dust-bathing bouts in all systems. During the OP 1, the hens in systems D and E dust-bathed longer ($P = 0.05$, Mann–Whitney U test) than those in systems A, B, and C, in which dust-bathing duration did not exceed 4.5 min. During the OP 2, the hens in systems A and E dust bathed longer than those in systems B and D ($P = 0.05$, Mann–Whitney U test), and during the OP 3, the hens in systems A, C, and E dust bathed longer than those in system B ($P = 0.05$, Mann–Whitney U test). In system B, dust-bathing bouts with the shortest average duration were observed during all OPs, and the longest dust-bathing bout in this system lasted 5.6 min.

Disrupted terminations and interruptions were caused mainly by pecking (Reason Score "1") or being pushed from the dust-bath area by another hen (Reason Score "2"). However, at numerous times, no obvious reasons for the terminations and interruptions could be observed (Reason Score "0", Table 4).

The interruption of dust bathing was seen more frequently in systems A, C, and D than in system E during all OPs (Table 4). During the OPs 2 and 3, this difference was significant ($P = 0.05$, chi-square test). System B could not be included in the statistical evaluation due to the small number of dust-bathing bouts performed in this system. The assessment of the average relative number of dust-bathing interruptions included repeatedly-interrupted dust-bathing bouts. The likelihood of interruptions ranged from 18.5 to 78.3% in systems A, C, and D. However, mostly (in 8 of 9 recorded OPs, considering systems A, C, and D with 3 OPs each) the dust-bathing bouts were interrupted in more than 40.0% of the cases. In system E, the likelihood of an interruption of a dust-bathing bout ranged from 0 (no interrupted dust bath in OP 3) to 13.5%. The mean duration of an interruption ranged from 10 to 38 s and differed only slightly between the housing systems.

Differences between the enriched colony housing systems (A, C, and D) and the aviary system (E) were observed in terms of termination of the dust-bathing bouts (Table 4). During all 3 OPs, it was never recorded that all (100%) of the dust-bathing bouts in any of the

Table 5. Comparison of systems A to E in terms of the average duration of a dust-bathing bout in minutes over 3 observation periods (OP) and presented as mean value (MV), minimum (min.), and maximum (max.) of observed duration. SD = Standard deviation; SEM = standard error of the estimate of the mean value; Aw = age in wk; n = number of observed dust baths.

		OP 1 (24–25 Aw)		OP 2 (47–48 Aw)		OP 3 (63–64 Aw)		MV OPs 1–3	
System A	min.	$n = 29$	0.15	$n = 24$	0.70	$n = 27$	0.18	$n = 80$	0.15
	MV		3.54		10.04		8.00		7.00
	max.		20.92		35.38		21.15		35.38
	SD		4.21		6.92		6.43		6.43
	SEM		0.78		1.41		1.24		1.24
System B	min.	$n = 5$	0.25	$n = 4$	0.37	$n = 9$	0.52	$n = 18$	0.25
	MV		1.89		1.95		2.81		2.36
	max.		3.28		4.00		5.60		5.60
	SD		1.18		1.61		1.80		1.59
	SEM		0.53		0.81		0.60		0.37
System C	min.	$n = 63$	0.07	$n = 76$	0.13	$n = 59$	0.13	$n = 198$	0.07
	MV		4.05		7.77		8.75		6.88
	max.		17.05		28.23		36.68		36.68
	SD		4.55		6.96		7.32		6.68
	SEM		0.57		0.80		0.95		0.47
System D	min.	$n = 56$	0.32	$n = 78$	0.10	$n = 39$	0.23	$n = 173$	0.10
	MV		8.57		6.79		7.01		7.42
	max.		44.03		24.33		31.40		44.03
	SD		9.04		6.28		7.28		7.50
	SEM		1.21		0.71		1.17		0.57
System E	min.	$n = 35$	1.22	$n = 46$	0.47	$n = 24$	0.38	$n = 105$	0.38
	MV		10.61		9.46		8.45		9.61
	max.		31.67		26.68		31.28		31.67
	SD		8.21		7.84		7.26		7.81
	SEM		1.39		1.16		1.48		0.76

systems ended "normally." However, in system E, more than 80% of the observed dust-bathing bouts during all OPs ended normally. Only in this system (aviary system), more dust-bathing bouts were terminated normally rather than by disrupting influences during all OPs ($P = 0.05$, chi-square test). In system A, the ratio between dust-bathing bouts that ended normally versus disrupted did not differ during any OP, and on average 48.3 to 54.2% of the observed dust-bathing bouts were terminated normally in this system. In system C, more dust-bathing bouts (67.1%) were terminated normally than by a disruption during the OP 2 ($P = 0.05$, chi-square test). In system D, fewer dust-bathing bouts (35.9%) were terminated normally than disrupted during the OP 2 ($P = 0.05$, chi-square test), and the maximal percentage of normal dust-bathing termination was 50.0%, observed during the OP 1.

DISCUSSION

The fewest dust-bathing bouts in terms of absolute numbers and when observed over the course of the day were recorded in the enriched housing system B, which had the most ($n = 4$) but the smallest (792 cm^2 each) dust-bath areas. In systems C and D, the enriched colony housing systems with larger and connected dust-bath areas, more dust-bathing bouts were recorded. A positive correlation between the size of the dust-bath area and the dust-bathing activity was observed. These results confirmed previous observations from other authors, who reported that larger areas were preferred by laying hens and led to increased dust-bathing activities (Appleby et al., 1993; Abrahamsson et al., 1996; Telle, 2011; Döring, 2012).

In all 4 enriched colony housing systems of the present study, but not in the aviary system, sham dust bathing on the wire mesh could be observed during all OPs to a varying degree, showing a negative correlation between the size of the dust-bath area and the prevalence of sham dust bathing on the wire mesh. Dust bathing on wire mesh was observed by other authors (Vestergaard, 1987; Lindberg und Nicol, 1997; Olsson et al., 2002; Orság et al., 2011), even when other dust-bath areas were provided. Pohle and Cheng (2009) never observed dust bathing on wire mesh, no matter whether hens were held in conventional or in furnished cages. However, as they observed preening in furnished cages but signs of stress in conventional cages, they concluded that only the furnished cages allowed hens to perform normal behavior. Opposite to the conclusions of most authors, Guesdon and Faure (2008) claimed that loose litter material is not necessary to satisfy hens' dust-bathing motivation because the hens in their study seemed satisfied with any offered material including litter, Astroturf®, or wire mesh.

In our study, particularly in systems A and B, the hens showed significantly more sham dust-bathing behavior on the wire mesh than dust bathing in the provided areas during several OPs. In systems C and D on the other hand, although sham dust bathing occurred as well, it was observed significantly less than normal dust bathing. The dust-bath areas provided in systems A and B were smaller than those in systems C and D, and were separated into 2 (system A) and 4 (system B) sections. In systems C and D, which provided larger and connected dust-bath areas, the hens showed not only more dust-bathing activity but also less sham dust bathing than in systems A and B.

In line with the observations of other authors, the hens in systems A and B showed sham dust-bathing behavior on the wire mesh mainly near the feeding trough. Lindberg and Nicol (1997) made similar observations and concluded that hens did not show a "vacuum" behavior because they were using the food in the trough as a substrate. In our study, sham dust bathing near the feeding trough occurred predominantly in those systems in which less dust-bathing behavior was seen in the provided areas and more sham dust bathing was seen overall. This leads to the question whether the hens used the feed in the trough and the area in front of the trough in systems A and B as an alternative litter material and dust-bath area to compensate for the potentially insufficient material or dust-bath area in these systems. This hypothesis is supported by the fact that in those systems with larger (system C) and connected dust baths (system D), sham dust bathing occurred less overall and less frequently near the feed trough.

De Jong et al. (2007) reported that no sham dust-bathing behavior was observed and that they could not identify a strong general preference for any of the examined substrates (peat moss, sand, wood shavings) or a preference for these substrates over a wire floor. In their experiments, laying hens, which were housed in a custom-built test area consisting of a home pen and adjoining areas with various resources, were allowed (and trained) to choose access to various dust-bathing options. However, the behavior shown after the hens got access to the specific substrate varied, with more dust-bathing behavior being shown on peat moss than on the other substrates. No clear substrate preferences were observed for foraging (De Jong et al., 2007).

In the present study, the average duration of dust-bathing bouts varied in all systems but in system B (with the smallest individual dust-bath areas) did not exceed 3 min during any of the OPs (with the longest recorded dust-bathing bout in this system lasting 5.6 min). Only the hens in system D showed longer dust-bathing bouts with durations between 5 and 10 min during all OPs. Compared with the durations of 20 to 30 min under natural conditions, the herein observed dust-bathing bouts were distinctly shorter in all of the enriched colony housing systems and the aviary system. These findings confirm the results of other authors, who reported dust-bathing durations of 5 to 10 min in enriched cages (Appleby et al., 1993; Sewerin, 2002; Hergt, 2007; Orság et al., 2011; Telle, 2011). Furthermore, no correlation between the size of the dust-bath area in the enriched colony housing systems and the duration of the dust-bathing bouts was observed. The very short average duration of a dust-bathing bout of less than 5 min may be explained by lack of efficiency of the substrate during the introductory phase. Van Liere et al. (1990) reported that with such short dust-bathing duration (≤5 min) just the introductory phase, i.e., the phase when the substrate is distributed between the feathers, could be completed. The authors concluded that hens terminated the dust bathing prematurely due to an unsuccessful introductory phase, because it was incomplete.

It seems noteworthy that, with one exception, we could not observe in any system during any OP a completely normal dust-bathing activity, in terms of 100% of the dust-bathing bouts being uninterrupted and terminated normally. Only in system E, the aviary system, and only during the OP 3, none of the observed dust-bathing activities was interrupted. A common reason for premature termination was a disruption caused by other hens, also described by Vestergaard (1987), Hergt (2007), and Telle (2011). The ratio of dust-bathing bouts that were terminated normally ranged between 25 and 89% in the enriched colony housing systems and between 83 and 91% in the aviary system. System B could not be included in a statistical analysis regarding this matter due to the small number of observed dust-bathing bouts. In systems A, C, and D during all OPs, a relative average of at least 18.5 up to 78.3% of the observed dust-bathing bouts were interrupted (including multiply-interrupted bouts), whereas in system E, merely a relative average of 0 to 13.5% of dust-bathing bouts were interrupted. These results indicated that dust-bathing behavior often could not be terminated without disruption, but they did not confirm results of another study in which all of the dust-bathing sequences were prematurely terminated through disrupting influence (De Jong et al., 2006).

Colson et al. (2007) concluded that hens can rather satisfy their dust-bathing behavior in aviary systems than in cages and that the high motivation to dust bathe in cages derives from a deprivation of litter. In our study, the numbers of dust-bathing bouts and the fractions of dust-bathing hens varied greatly, and there was no clear differentiation between the cages and the aviary system. However, we found a high correlation between the size of the individual dust-bath mats and the dust-bathing activity in the enriched colony housing systems. Our results on the likelihood of interruptions showed that dust-bathing bouts could not at all times be conducted according to the hens' species-specific behavior but were disturbed frequently. This was the case in the aviary system, yet more often in the enriched colony housing systems.

Measures to optimize the enriched colony housing systems in view of enhancing the possibility to perform normal dust-bathing behavior therefore appear necessary. Such measures should, according to the results of this study, affect the dust-bath area. The entire dust-bath area should be one connected (not subdivided) area to improve its suitability regarding the overall use, as well as the interruption and termination of dust-bathing behavior. Other functional areas, such as the drinking or feeding trough and perches, should not cross or be directly above the dust-bath area. The results of this study are based on a test with only a few replications and should be verified in a project that includes a greater number of replications.

ACKNOWLEDGMENTS

This project was supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the innovation support program.

REFERENCES

Abrahamsson, P., R. Tauson, and M. C. Appleby. 1996. Behaviour, health and integument of four hybrids of laying hens in modified and conventional cages. Br. Poult. Sci. 37:521–540.

Alvino, G. M., C. B. Tucker, G. S. Archer, and J. A. Mench. 2013. Astroturf as a dustbathing substrate for laying hens. Appl. Anim. Behav. Sci. 146:88–95.

Appleby, M. C., S. F. Smith, and B. O. Hughes. 1993. Nesting, dust bathing and perching by laying hens in cages: effects of design on behaviour and welfare. Br. Poult. Sci. 34:835–847.

BMELV. 2012. 86 Prozent aller Legehennen in Boden-, Freiland- und Öko-Haltung. Pressemitteilung 93, Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, 29.3.2012. http://www.bmelv.de/SharedDocs/Pressemitteilungen/2012/93-Legehennen.html (last accessed 3/25/2013).

BVerfG. 2010. BVerfG, 2 BvF 1/07 vom 12.10.2010, Absatz-Nr. (1–135), Bundesverfassungsgericht, Entscheidungen. http://www.bverfg.de/entscheidungen/fs20101012_2bvf000107.html (last accessed 5/3/2015).

Colson, S., C. Arnoul, and V. Michel. 2007. Motivation to dust-bathe of laying hens housed in cages and in aviaries. Animal. 1:433–437.

De Jong, I. C., M. Fillerup, B. Reuvekamp, and T. Fiks. 2006. LayWel, Welfare implications of changes in production systems for laying hens, Deliverable 4.5, Evaluation of substrate quality in two different housing systems (barn system and furnished cages) for laying hens with respect to dustbathing and foraging behaviour. SSPE-CT-2004-502315. Animal Sciences Group of Wageningen UR, Division of Animal Husbandry, AB Lelystad, The Netherlands.

De Jong, I. C., M. Fillerup, and C. G. van Reenen. 2007. Strength of preference for dustbathing and foraging substrates in laying hens. Appl. Anim. Behav. Sci. 104:24–36.

Döring, S. 2012. Exploratory and dust-bathing behaviour in laying hens kept in commercial aviaries and furnished cages. Diss., Dr. agr., University of Kassel, Witzenhausen, Germany.

EFSA. 2005. The welfare aspects of various systems of keeping laying hens, Opinion of the Scientific Panel on Animal Health and Welfare (AHAW) on a request from the Commission related to the welfare aspects of various systems of keeping laying hens. EFSA J. 197:1–23. http://www.efsa.europa.eu/de/efsajournal/doc/197.pdf (last accessed 1/18/2013).

Engelmann, C. 1984. Leben und Verhalten unseres Hausgeflügels. Neumann Verlag Leipzig, Radebeul, Germany. VLN 151–310/63/84.

German Order on the Protection of Animals and the Keeping of Production Animals. 2006. Amended and promulgated on August 22, 2006, last changed on February 5, 2014. Verordnung zum Schutz landwirtschaftlicher Nutztiere und anderer zur Erzeugung tierischer Produkte gehaltener Tiere bei ihrer Haltung; Tierschutz–Nutztierhaltungsverordnung (TierSchNutztV) in der Fassung der Bekanntmachung vom 22. August 2006 (BGBI. I S. 2043), die durch Artikel 1 der Verordnung vom 5. Februar 2014 (BGBI. I S. 94) geändert worden ist.

Guesdon, V., and J. Faure. 2008. A lack of dust-bathing substrate may not frustrate laying hens. Eur. Poult. Sci. 72:241–249.

Hergt, F. 2007. Vergleichende Untersuchung zum Verhalten von Legehennen in Klein- und Großvolierenhaltung. Diss., Dr. med. vet., Ludwig-Maximilians-Universität München, Munich, Germany.

Lindberg, A. C., and C. J. Nicol. 1997. Dustbathing in modified battery cages: Is sham dustbathing an adequate substitute? Appl. Anim. Behav. Sci. 55:113–128.

Martin, C. D., and B. A. Mullens. 2012. Housing and dustbathing effects on northern fowl mites (*Ornithonyssus sylviarum*) and chicken body lice (*Menacanthus stramineus*) on hens. Med. Vet. Entomol. 26:323–333.

Martin, P., and P. Bateson. 2007. Measuring Behaviour, an Introductory Guide. Cambridge University Press, Cambridge, United Kingdom. ISBN 978-0-521-53-563-2.

Olsson, I. A. S., L. J. Keeling, and I. J. H. Duncan. 2002. Why do hens sham dustbathe when they have litter? Appl. Anim. Behav. Sci. 76:53–64.

Olsson, I. A. S., and L. J. Keeling. 2005. Why in earth? Dustbathing behaviour in jungle and domestic fowl reviewed from a Tinbergian and animal welfare perspective. Appl. Anim. Behav. Sci. 93:259–282.

Orság, J., J. Brouček, L. Mačuhová, M. Knížatová, P. Fl̆ak, and A. Hanus. 2011. Behaviour of hens deprived of dustbathing. Slovak J. Anim. Sci. 44:65–71.

Petherick, C. J., E. Seawright, D. Waddington, I. J. H. Duncan, and L. B. Murphy. 1995. The role of perception in the causation of dustbathing behaviour in domestic fowl. Anim. Behav. 49:1521–1530.

Pohle, K., and H.-W. Cheng. 2009. Furnished cage system and hen well-being: comparative effects of furnished cages and battery cages on behavioral exhibitions in White Leghorn chickens. Poult. Sci. 88:1559–1564.

RL1999/74/EG. 1999. Richtlinie 1999/74/EG des Rates vom 19. Juli 1999 zur Festlegung von Mindestanforderungen für den Schutz von Legehennen (ABl. L 203, 3.8.1999).

Sanotra, G. S., K. S. Vestergaard, J. F. Agger, and L. G. Lawson. 1995. The relative preferences for feathers, straw, wood-shavings and sand for dustbathing, pecking and scratching in domestic chicks. Appl. Anim. Behav. Sci. 43:263–277.

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

Scholz, B., J. B. Kjaer, S. Urselmans, and L. Schrader. 2011. Litter lipid content affects dustbathing behavior in laying hens. Poult. Sci. 90:2433–2439.

Sewerin, K. 2002. Beurteilung der Tiergerechtheit des angereicherten Käfigtyps “Aviplus” unter besonderer Berücksichtigung ethologischer und gesundheitlicher Aspekte bei Lohmann Silver Legehennen. Diss., Dr. med. vet., Tierärztliche Hochschule Hannover, Germany.

Telle, M. 2011. Verhaltensbeobachtungen bei der Kleingruppenhaltung von Legehennen (LSL). Diss., Dr. med. vet., Ludwig-Maximilians-Universität München, Munich, Germany.

Van Liere, D. W., J. Kooijman, and P. R. Wiepkema. 1990. Dustbathing behaviour of laying hens as related to quality of dustbathing material. Appl. Anim. Behav. Sci. 26:127–141.

Van Rooijen, J. 2005. Dust bathing and other comfort behaviours of domestic hens. Pages 110–123 in Das Wohlergehen von Legehennen in Europa — Berichte, Analysen und Schlussfolgerungen (28). G. Martin, H. H. Sambraus, and C. Steiger, eds. Internationale Gesellschaft für Nutztierhaltung IGN, Verlag Universität Kassel, Germany. ISBN 3-00-015577-5.

Vestergaard, K. 1982. Dust-bathing in the domestic fowl — diurnal rhythm and dust deprivation. Appl. Anim. Ethol. 8:487–495.

Vestergaard, K. 1987. Dust-bathing of hens with and without access to sand. Appl. Anim. Behav. Sci. 17:380.

Vestergaard, K., and E. Baranyiova. 1994. The control of dustbathing by pecking in young chicks. Appl. Anim. Behav. Sci. 40:98.

Vestergaard, K., E. Skadhauge, and L. G. Lawson. 1997. The stress of not being able to perform dustbathing in laying hens. Physiol. Behav. 62:413–419.