Applied Animal Behaviour Science 253 (2022) 105686

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Piling behaviour in British layer flocks: Observations and farmers` experiences

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ARTICLE INFO

Keywords:
Smothering
Cage-free systems
Gregarious behaviours
Diurnal behaviours
Flock age

ABSTRACT

Smothering of laying hens, defined as death due to suffocation when hens tightly pile together in layer barns, is a well-known problem affecting the British loose-housed layer industry. However, knowledge about mechanisms contributing to piling in British layer flocks remains anecdotal. To understand piling behaviour mechanisms, the behaviour of 27 British loosed-house layer flocks from two farmer organisations (four brown hybrids, twenty large barns with a flock size of median ± SD, 10 175 ± 5721 birds, and seven small mobile barns, flock size: 2000 ± 0 birds) with a history of piling behaviour was observed. Video observations were taken along walls and in the centre of the floor area of the layer barns. The number of piles, pile sizes, pile durations, events preceding piles, and locations where piles started (wall/floor area) were described for one day (08:30–16:00 h) at three times of day (0–4 h, >4–8 h, >8–12 h after lights on) either around 20 weeks or around 30 weeks of flock age. Events preceding piling were analysed using descriptive statistics. The effects of time of day, flock age, laying hen hybrid, the area where piles started, and colony size on the number of piling events, pile sizes, and pile durations were assessed using univariate analysis and linear or generalised linear mixed-effects models in R. In addition, twelve British farmers, a subset of the investigated farms, were interviewed about their experiences with piling and smothering. Interviews were audio-recorded, transcribed, and analysed using qualitative content analysis. In total, 92 piles were detected in the videos, lasting on average 21.9 ± 29.3 min and involving 25 ± 39 hens. Piles were mostly preceded by the attraction of hens to other hen behaviours (63.0%) and bird movements through high animal densities on the floor area (23.0%). Piles occurred significantly more frequently at > 4–8 h compared to > 8–12 h and 0–4 h after lights on. Pile sizes were larger in the floor area centre than along walls and positively correlated with pile durations and the flock sizes. Interview analysis revealed that farmers considered multiple events to be triggers for piling and smothering, including the transfer from the rearing to the laying environment, flight responses, broken routines, gregarious nesting in nests or on the floor area, and other gregarious behaviours such as dustbathing in the centre of the floor area. They reported that the causes of piling and smothering change throughout the flock cycle and time of day.

1. Introduction

Smothering, suffocation when laying hens pile together on the floor area, is a widely distributed and substantial problem affecting the loose-housed egg industry. For example, a survey including 206 British farmers, revealed that smothering affects nearly 60% of flocks (Barrett et al., 2014), and a study quantifying losses on British flocks, showed that smothering can account for one-sixth (15.5%, 2.53–38.4%) of the annual flock mortality (Nicol, 2012). Unsurprisingly, 26.0% of surveyed British farmers perceive smothering as a substantial problem (Barrett et al., 2014).

Despite the relevance of understanding smothering in British layer flocks, information about mechanisms contributing to smothering has remained scarce (Barrett et al., 2014; Gray et al., 2020; Rayner et al., 2016). For example, previous studies differentiated panic smothering, nest box smothering and creeping smothering but their occurrence lack

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https://doi.org/10.1016/j.applanim.2022.105686
Received 7 March 2022; Received in revised form 17 June 2022; Accepted 21 June 2022
Available online 24 June 2022

explanations (Bright and Johnson, 2011; Gray et al., 2020). Furthermore, while a survey study associated smothering with various causal factors including locations (e.g., barn corners, the centre of the floor area), time of day (e.g., morning, midday, afternoon, evening), and flock age (<20 weeks - >45 weeks) (Barrett et al., 2014), these associations have not been quantified.

One major obstacle in the investigation of smothering is its unpredictable nature. For example, although Barrett et al. (2014) surveyed more than two hundred farmers about smothering in their flocks, relations between smothering and potential explanatory factors, such as time of day, flock age, or location in the barn, could not be established. Furthermore, video observations of smothering suggest that smothering occurs randomly throughout the flock cycle (Herbert et al., 2021), making it difficult to know when and where to focus observations or identify explanatory factors for smothering.

Because of the unpredictability of smothering, recent studies have studied piling behaviour, operationalised as "three or more mostly immobile hens standing in the closest possible proximity, with most hens facing in the same direction" (Winter et al., 2021), which can lead to smothering (Herbert et al., 2021; Winter et al., 2021). Although piling behaviour was frequently observed in only two published British studies (Gibson et al., 1985; Herbert et al., 2021), little is known about piling risk factors in British layer flocks. Although sunlight (Gibson et al., 1985), higher temperature ranges, and times around midday were associated with the occurrence of piling (Herbert et al., 2021), each of those studies investigated piling in only one flock, limiting extrapolation to British flocks in general.

More is known about piling behaviour in Switzerland and North America. For example, two studies found that specific events can precede piling including hens being attracted to conspecifics` behaviours, bird movements on the floor area, or attraction of hens to light spots (Campbell et al., 2016; Winter et al., 2021). Furthermore, piling in Swiss flocks was related to flock age (e.g., longer-lasting piles at 20 weeks compared to 30 weeks of age) and time of day (e.g., higher piling frequencies at midday than in the morning and afternoon in white flocks) (Winter et al., 2021). However, it cannot be assumed that the findings from those studies will apply to British flocks. For example, although Winter et al. (2021) included multiple (n = 13) flocks in their study, differences between British and Swiss flocks in terrms of flock size (e.g., 4′000–6′000 birds vs. up to 18′000 in British vs. Swiss flocks, respectively), and management (e.g., British housing 16 weeks of age versus 18 weeks of age in Switzerland) limit comparisons. Furthermore, the Swiss study investigated piling behaviour in barn corners (Winter et al., 2021), while British farmers` responses on smothering suggest that piles can also occur in the centre of the floor area (Barrett et al., 2014).

To improve the understanding of piling in British layer flocks, the first objective of this study was to describe piling preceding events and piling characteristics (i.e., number of piles, pile durations, pile sizes) by video recording multiple flocks. We predicted that smothering would be more likely to occur at times and locations with higher piling activities (i.e., higher piling incidences, longer piles, larger pile sizes) (Winter et al., 2021). The second objective was to identify explanatory factors of observed piling characteristics. Given previous reports on piling and smothering, it was hypothesised that time of day, flock age, hybrid, colony size, and the location where piles start would moderate their characteristics (Barrett et al., 2014; Campbell et al., 2016; Winter et al., 2021). The third objective was to explore farmers' experiences of preceding events and explanatory factors of piling and smothering by applying qualitative methods. Based on previous survey results (Barrett et al., 2014), it was assumed that farmers are knowledgeable in identifying preceding events and explanatory factors of piling and smothering.

2. Methods

2.1. Ethics

The study was ethically approved by the Clinical Research Ethical Review Board (CRERB, URN 2019 1900–2) and by the Social Science Research Ethical Review Board (SSRERB, URN SR2020–0230) of the Royal Veterinary College, London. All participating farmers were informed about the study objectives and gave written consent to participate in the study. Any potentially identifying information was anonymised.

2.2. Flocks

Video data were collected between January and August 2020 on 27 British loose-housed flocks (all birds that are kept in the same building) that were kept on 20 farms and consisted of 37 colonies (sub-divisions of flocks) in the area of North England and South Scotland in the United Kingdom. Two sizeable British egg farmer organisations established contact between the researchers and their farm managers of flocks with a history of piling and smothering. Flocks of farmer organisation 1 (20 flocks kept on 13 farms, flock size: median ± SD, 10 175 ± 5721 birds, colony size: median ± SD, 4000 ± 852 birds, here named "large barns") were kept in aviary housing systems or flat deck systems with perches with free range access. Flocks of farmer organisation 2 (seven flocks kept on seven farms, flock size: median ± SD, 2000 ± 0 birds, colony size: median ± SD, 2000 ± 0 birds) were kept in mobile barn perch systems (in the following named "mobile barns") from the same manufacturer providing access to a range and a roof-covered veranda. Most farmers had only limited information on the specific rearing systems used. Further flock descriptions are provided in Table 1.

2.3. Video recordings

The flock behaviour was video-recorded at approximately 20 (20.5 ± 2.6 w, nine flocks) or 30 weeks (31.7 w ± 5.7 w, 18 flocks) of flock age, based on previous work suggesting that smothering and, thus, piling behaviour is most frequent at these flock ages (Barrett et al., 2014; Bright and Johnson, 2011). The flock behaviour in barns with electrical power availability (seven large barns on seven farms including ten colonies) was recorded with a Hikvision recording system (DS-7608NI-K2–8 P, 8-channel, Network Video Recorder, Hangzhou Hikvision Digital Technology Co. Ltd., Hangzhou, China) and six infrared-sensitive, high-resolution, wide-angled video cameras (Panasonic WV sp105 IP network camera and Panasonic WV-SPW312L HD Bullet Camera, Panasonic Corporation, Osaka, Japan). The flock behaviour in barns where installation of the recording system was not possible due to limited electrical power access (seven mobile barns including seven colonies) or SARS-COV2 restrictions (13 large barns on six farms including 20 colonies) was recorded with infrared-sensitive mini video recorders (HD 1080p, euskDE, ASIN: B0836RDRPP). In large barns consisting of one colony, the cameras were placed in two barn corners (one front and one back corner) and four locations evenly distributed along the barn length. In large barns consisting of more than one colony, six cameras were installed in the first two colonies: two in corners (one front barn corner, one corner after a colony separation), and two evenly distributed in each colony (Supplements, Fig. 1). In mobile barns, three cameras were installed: two cameras in barn corners (one front right, one back left) and one camera in the front corner of the scratch area (Supplements, Fig. 2). All cameras in large and mobile barns were directed towards the floor area. Cameras were always placed at barn sides with pop hole exits. In large barns, cameras covered approximately 5–10 m^2 floor area and in mobile barns, 2–6 m^2 depending on the available mounting height and camera type.

Table 1
Flock characteristics of investigated flocks where piling was observed. Each farmer organisation (Organisation) had several farms that could have several flocks. Hybrid: SB = Shaver Brown, LB = Lohmann Brown, LC = Lohmann Classic, BB = British Blacktail. Housing: AV=Aviary, FD = Flat deck, MB=Mobile barn. Recording system A refers to mounted wide-angle cameras (Panasonic WV sp105 IP network cameras and Panasonic WV-SPW312L HD Bullet cameras). Recoding system B included portable mini video recorders (HD 1080p, euskDE, ASIN: B0836RDRPP).

Organisation	Farm ID	Flock	Hybrid	System	Housing	Flock size	Colony size	Flock age (weeks)	Recording System
1	1	1	SB	Free range	FD	3000	3000	29	A
1	2	1	SB	Free range	FD	16000	4000	21	A
1	3	1	SB	Free range	FD	10350	4000	18	A
1	4	1	LB	Free range	FD	8000	4000	18	A
1	5	1	SB	Free range	FD	16000	4000	24	A
1	6	1	SB	Free range	FD	16000	4000	31	B
1	6	2	SB	Free range	FD	16000	4000	31	B
1	7	1	SB	Free range	FD	6000	6000	29	B
1	8	1	SB	Free range	FD	10000	4000	35	B
1	9	1	LB	Free range	FD	12000	4000	30	A
1	10	1	LC	Free range	AV	16000	4000	32	B
1	10	2	LC	Free range	AV	16000	4000	32	B
1	11	1	SB	Organic	FD	3000	3000	28	B
1	11	2	SB	Organic	FD	3000	3000	28	B
1	11	3	SB	Organic	FD	3000	3000	28	B
1	11	4	SB	Organic	FD	3000	3000	28	B
1	11	5	SB	Organic	FD	3000	3000	28	B
1	12	1	SB	Free range	AV	16000	4000	32	B
1	12	2	SB	Free range	AV	16000	4000	32	B
1	13	1	LB	Free range	FD	6000	6000	32	A
2	14	1	BB	Organic	MB	2000	2000	33	B
2	15	1	BB	Organic	MB	2000	2000	24	B
2	16	1	BB	Organic	MB	2000	2000	22	B
2	17	1	BB	Organic	MB	2000	2000	53	B
2	18	1	BB	Organic	MB	2000	2000	18	B
2	19	1	BB	Organic	MB	2000	2000	22	B
2	20	1	BB	Organic	MB	2000	2000	18	B

Fig. 1. Piling behaviour at the end of a barn aisle in a layer flock consisting of 16.000 hens divided into four colonies. The pile was preceded by a group of hens walking through hens synchronously dustbathing at midday on the floor at an area with uneven light intensity.

2.4. Video assessment

The flock behaviour was assessed in all recorded flocks (27 flocks) at each recorded camera location (70 different camera locations) for one day between 08:30 h and 16:00 h. Piling was recorded when three or more mostly immobile (maximal movement duration below five seconds) hens were standing in the closest possible proximity (overlapping of body outlines, no bird distance, see Fig. 1), with most hens facing in the same direction (Winter et al., 2021). The suitability of the definition was evaluated from preliminary video observations on British flocks and the similarity of piles observed. A one-minute scan sampling technique was applied to identify piles. Scan sampling was applied to identify piles. Videos were forwarded successively by 1 min intervals until a pile was identified, at which point the precise pile start and end times were assessed by forwarding and reversing the video. Only those piles with durations of more than 1 min were considered in the analysis because some piles of shorter duration could have been missed by this technique.

The pile duration, the number of hens per pile (pile size), the areas where the pile started and events preceding piling behaviour were assessed for each identified pile. The pile duration was assessed by calculating the period between the pile start time and the pile end time. A piling event started when all conditions of the piling definition were fulfilled and ended when one of the conditions was absent. The pile size was assessed by averaging the counted number of combs or, when hens crawled under the pile, tail tips of hens involved in the pile at 1/4, 1/2 and 3/4 of the pile duration at the video monitored area. When the number of piling hens exceeded the video monitored area, they were kept in the analysis. Accordingly, pile sizes may be underestimated which should be considered in the data interpretation. The area where piles started was assessed by identifying where the hen behaviour fulfilled the piling definition first (e.g., in the centre of the floor area or along barn walls). Piling preceding events were described when visible on the video as changes in the environment or behaviour of the hens at the time and location when the piling event started. One observer (JW), with a 2-years experience of analysing piling behaviour, assessed all videos.

2.5. Statistical analysis

The statistical analysis was performed in R using the user surface Rstudio (R development core team, 2020; Rstudio Team, 2020). Data were cleaned using the packages “tidyR” (Wickham and Henry, 2020). The dataset was checked for outliers, collinearity, interactions, and data distribution assumptions following a standard protocol (Zuur et al., 2010). Response variables throughout the analysis included all piling characteristics, i.e., the number of piles, pile duration (in min), and mean pile size. Explanatory variables were all categorical and included: time of day (0–4 h, >4–8 h, >8–12 h), flock age (around 20 w or 30 w of age), and areas where piles started (centre of the floor area, along walls). The descriptive analysis of explanatory variables was performed by applying the R-package “dplyr” (Wickham et al., 2020). In a subsequent univariate analysis, associations between all explanatory variables and dependent variables were assessed by linear regression models (for pile duration and average pile size) and generalised linear regression models (for pile number). Tukey's honest significance tests were employed to assess differences between the levels of the explanatory variables. Furthermore, correlations between colony size and all piling characteristics and between pile size and pile duration were assessed using Spearman's correlation scatterplots ("ggpubr", Kassambara, 2020). The housing system (i.e., large barns, mobile barns) was not included as an explanatory variable in the univariate analysis, as it was confounded with colony size. Explanatory variables associated with the piling characteristics ($p < 0.2$) in the univariate regression analyses were further assessed in multivariate models. The multivariate models were linear (for pile duration and average pile size) and generalised linear mixed-effects models (for pile number) (lme4, Bates et al., 2015). The multivariate models included the pre-identified relevant explanatory variables and the covariates flock age, hybrid (Shaver Brown, brown Lohmann hybrids (Lohmann Classic, Lohmann Brown), British Blacktail) and colony size. The covariates flock age and hybrid were found (Winter et al., 2021) and colony size suggested (Campbell et al., 2016) to influence piling behaviour. However, it was not possible to balance hybrid and colony size in the data collection process, wherefore they were included as covariates. Although flock age was not associated ($p < 0.2$) with piling characteristics in the univariate analysis, it was still included as a covariate to to account for age effects reported by (Winter et al., 2021). The random term time of day (1| time of day), crossed with the random term area where piles started (i.e., wall / centre of the floor area) nested in recorded location (i.e., camera position in relation to the distance and entrance of the shed), colony (colony position in the shed in relation to the entrance, i.e., first, second, third colony), flock (flock ID), farm (farm ID), and farmer organisation (1 | farmer organisation/farm/flock/colony/recorded location/areas where piles started), was included in all models. Including the recorded location as a random term accounted for differences in the covered floor area space. In addition, analysing the model by following a hierarchical structure including flocks and the recorded locations, controlled for differences in the number of recorded locations per flock. In the generalised linear mixed-effects models, the model performance optimiser "bobyqa" was applied, including a maximum of 100′000 iterations. The most parsimonious model of each piling characteristic was selected by comparing Akaike Information Criterion (AICc) differences (corrected for small sample sizes) and AICc weights (AICcmodavg, Mazerolle, 2020) between all possible model candidates. Values of AICc differences < 2 were treated as substantial (Burnham and Anderson, 2004, p.271) and used to determine retention of model factors. Model assumptions for the linear mixed-effects models were checked, including the visual assessment of QQ-plots. The model fit was checked for generalised linear-mixed effects models using QQ-Plots (DHARMa, Hartig, 2018). The effects of the full model were calculated using the package "effects" (Fox and Weisberg, 2018). Visual confidence interval (alpha=0.95) comparisons of the model estimates were calculated. Tukey's honest significance tests were applied to assess statistical differences between groups (multcomp, Hothorn et al., 2008) in the final model. Model effects were plotted by applying the package ggplot2 (Wickham, 2016).

2.6. Selection of interview participants

A subset of farmers of the video recorded farms was interviewed between June and December 2020 about their experiences with piling behaviour and smothering. The participant selection followed a pragmatic and explorative approach. First, the farmer organisations were asked to list participants at least 18 years or older and having experienced piling behaviour and smothering in their previous flocks. Second, the suggested participants were contacted via phone, text, or e-mail, and those expressing interest in being interviewed on piling behaviour and smothering were included in the study (12 participants).

2.7. Interviews

The interviews were conducted by one researcher and followed a semi-structured approach supporting the exchange of information. The interviews started with explaining the project purpose and each step involved in the study. Furthermore, the researcher introduced himself as a veterinarian conducting his PhD on piling behaviour and smothering. After asking the participant to speak openly about their experiences with piling behaviour and smothering in their current and previous flocks, a topical guide including guiding questions was used to elaborate on particularities of piling behaviour and smothering on each farm (Supplements, Table 1). The focus of the interviews (i.e., the extent to which farmers talked about piling behaviour or smothering) was primarily led by the participant. Six participants were interviewed face-to-face on their farms and six participants remotely (Skype). All interviews were recorded using the audio recording function of a portable video recorder (euskDE, ASIN: B0836RDRPP) placed within approximately 50–100 cm of the participant or within 10 cm of the laptop's speaker for video calls (Lenovo Ideapad 320 s, Lenovo Group Limited, Hongkong, China) ensuring high audio quality. In most cases (11), one participant at a time was interviewed. However, in one case, two participants responsible for the same flock were interviewed in the same interview and given the consistency of their responses, treated as one data source (Supplements, Table 2).

2.8. Descriptive analysis of participants and interview characteristics

The descriptive analyses of participants and interview characteristics were performed in R using the user surface Rstudio (R development core team, 2020; Rstudio Team, 2020) and applying the package "dplyr" (Wickham et al., 2020).

2.9. Content analysis

Interviews were first transcribed verbatim and reduced to their manifest content (i.e., filler words, laughter, sighs were removed) using the transcribe function of Microsoft Word (Microsoft Office 365, Microsoft Corporation, Redmont, US). Subsequently, the transcripts were repeatedly read to better understand the overall interview content. The interviews were inductively analysed through content analysis (Elo and Kyngäs, 2008). Meaningful text fragments (one to a few sentences) in the cleaned transcripts related to the study's objective and additional content around each fragment supporting its context were highlighted and coded in sub-headings (commenting function Microsoft Word). All fragments and codes were then exported (Python script, based on https://carstenknoch.com/2018/02/qualitative-data-analysis-using-microsoft-word-comments/) to Microsoft Excel (Office 365, Microsoft Corporation, Redmont, US) in a tabular format. The fragments and codes were content-specifically and inductively clustered to overarching categories in Excel. After the categories sufficiently represented the response variation in the fragments, fragments were selected reflecting the categories` content best. One researcher (JW) performed the analysis in close discussion with a researcher (JMC) experienced in content analysis to ensure the reliability of identifying categories and selecting the fragments.

3. Results

3.1. Accuracy of measuring piling behaviour

To assess the reliability for one observer to detect piles, the start-times and end-times of 14.1% (13 piles) of all recorded piles in 35% of the flocks with identified piles (seven out of 20 flocks) were re-assessed at days where piling behaviour was previously detected and compared with the initial assessment. Average differences between assessed and re-assessed start times were 1.8 ± 2.1 min (median: 55 s)

Table 2

Piling characteristics based on the video observation on British layer farms. The presented data include the total pile number (number of observed piles per farm), and raw data means ± SD, minimum, maximum, and the median of pile sizes (average of the number of hens piling counted at 0.25, 0.5, and 0.75 of the pile duration) and pile durations (time between start and end of the pile). Pile numbers were assessed by counting the number of piles per farm, pile durations were the difference between start and end of the pile, and pile sizes represent the average of the number of hens involved in the pile at 0.25, 0.5, and 0.75 of the pile duration. In this table, farms, where no piling was observed were not included. IDs match with the IDs provided in the qualitative results section. Piles observed on farms 10 and 12 were recorded in multiple flocks (10: 3 flocks, 12: 2 flocks).

Farm	Pile number	Pile size				Pile duration in min			
ID	Count	Mean ± SD	Min	Max	Med	Mean ± SD	Min	Max	Med
2	1	4.3	4.3	4.3	4.3	1.27	1.2	1.2	1.2
3	14	53.4 ± 64.4	6.3	200	24.5	22.2 ± 23.0	1.0	67.1	10.0
4	5	26.9 ± 9.6	14.6	41.3	27.3	24.4 ± 21.4	2.5	58.0	22.0
5	10	51.3 ± 68.7	3.0	160	10.3	25.3 ± 39.0	1.4	128.8	6.1
6	1	25.0	25.0	25	25.0	69.1	69.1	69.1	69.1
7	2	47.1 ± 46.4	14.3	80	47.1	11.0 ± 12.7	2.0	20.0	11.0
8	3	9.2 ± 2.8	6.0	11	10.6	7.1 ± 7.3	1.8	15.5	4.0
9	4	36.3 ± 22.1	14.0	67	32.1	50.3 ± 41.9	1.3	97.0	51.5
10	4	16.7 ± 14.2	7.0	37.3	11.3	3.2 ± 3.0	1.0	7.7	2.0
11	6	6.2 ± 3.7	3.3	13.3	5.1	5.9 ± 6.4	1.3	18.8	3.5
12	21	9.3 ± 4.0	4.3	22.6	9.0	19.4 ± 22.4	1.3	66.6	5.6
13	11	27.8 ± 18.0	7.0	53	28.0	29.0 ± 42.3	1.1	139.8	10.0
15	4	7.4 ± 4.9	3.6	14.6	5.6	57.4 ± 64.7	4.8	148.2	38.3
17	5	7.2 ± 4.2	4.6	14.6	5.0	2.8 ± 1.2	1.4	4.1	2.9
18	1	5.3	5.3	5.3	5.3	2.0	2.0	2.0	2.0
Mean	6.13	22.2 ± 38.75	3.0	200	10.17	22.0 ± 30.8	1.0	148.2	5.6

and for pile-end times 6.0 ± 10.5 min (median: 2.3 min). Piles with larger pile end-time differences (two piles) were surrounded by a high level of moving hens, making it challenging to identify the end-time of the pile. To assess the reliability of pile sizes, 16.3% of piles (15 piles) observed in 65% of flocks with identified piles (13 out of 20 flocks) were re-assessed. On average, differences to assess pile sizes were 7.8 ± 12.3 birds (median: three birds), seeming low given the high average pile size (35 ± 55 birds) and on-farm conditions.

To assess the applicability of the piling definition for an inexperienced observer, the number of events when the hen behaviour fulfilled the piling definition, pile start-times, and end-times were assessed by a piling-inexperienced observer using 18 video snippets (mean: 32 min ± 13 min) and the results compared with the assessment of an experienced observer. The video snippets were randomly selected from 42% of all observed flocks (twelve out of 27 flocks), reflecting the variations of observed flocks and recording conditions (e.g., different video angles on the pile). The experienced observer pre-assessed the snippets as including piles in 12 out of 18 snippets (66.6%); the rest (six out of 18 snippets, 33.4%) were classified as not including piles. The novel observer agreed in 83.3% (15 out of 18 snippets) with the experienced observer regarding the snippets containing piles or not. Reasons for disagreement between observers included variation in the density of birds in piles (two events) and a high level of bird movement surrounding piling hens (one pile). For the agreed piles (twelve), the average differences of start-times were 2.3 ± 5.6 min (median: 25 s), and for end-times 3.2 ± 7.1 min (median: five seconds). To assess the performance of a novel observer to assess pile sizes, the novel observer assessed 15 pile pictures (16.3% of piles) of 65% of flocks (13 out of 20 flocks showing piling) and compared the results with the assessment of the experienced observer. On average, the pile size difference between observers were 23 ± 64 hens (median: three hens). High mean differences of pile sizes originated from two piles, where high animal densities of preening and dustbathing hens on the litter area made it challenging to differentiate piling hens.

3.2. *Descriptive analysis of piling behaviour*

In total, 92 piles (more than three hens, >1 min) were detected in the videos. Piles occurred in over sixty per cent of flocks (18/27 flocks, 66.6%), in seventy-five per cent of large barns (15/20 flocks, 75%), and forty per cent of mobile barns (3/7 flocks, 42%). In addition, piles were observed in fifty per cent of colonies (21/37 colonies, 56%) and forty per cent of the recorded locations (29/70, 41%). On average, piles lasted 21.9 ± 29.3 min (median: 5.6 min, 1.0–148.2 min) and involved 25 ± 39 animals (median: ten animals, 3–200 animals). Further characteristics of observed piles are presented in Table 2.

The attraction of hens to various other hen behaviours preceded more than fifty per cent of piles. About twenty-three per cent of piles were preceded by localised high animal densities and two per cent by hens following farm personnel leaving the barn. Events outside of the camera focus preceded ten per cent of piles. Further information about piling preceding events is presented in Table 3. Piles dissolved mostly by hens leaving (56 piles, 60.9%), starting dustbathing or preening (13 piles, 14.1%), starting other behaviours such as sitting (three piles, 3.2%), being dispersed by farm staff (seven piles, 7.6%), or agonistic interactions (two piles, 2.1%). For 8.7% (eight piles), the event dissolving the pile laid outside the camera focus. Piles could restart quickly

Table 3

Piling preceding events that were identified in the video recordings as the event happening at the time when and location where piling started. The table represents the number of piles preceded by a specific event and the percentages of the piling preceding events.

Preceding event	Frequency	%
I) The attraction of hens to conspecifics that were:	58	62.6
- Standing in barn corners	21	22.8
- Pecking at various barn items	13	14.1
- Brooding along walls and in corners	5	5.4
- Visible through a barn separation	5	5.4
- Egg-eating	4	4.3
- Resting along walls and in corners	4	4.3
- Floor nesting in corners	4	4.3
- Slipping out on slats	1	1.0
- Squeezing in a narrow wall gap	1	1.0
II) Localised high animal densities	22	23.8
- Non-hysteric group movement of birds in one direction of the floor area	12	13.0
- A group of hens walking through synchronous dustbathing and preening hens	8	8.7
- Unclear reason	2	2.1
III) Farm personnel	2	2.1
- Hens follow farm personnel leaving the barn and pile up in front of doors.	2	2.1
IV) Out of camera focus	10	10.8
Total	92	99.3%

after the previous pile was dissolved, often close to the same spots in the centre of the floor area. None of the described piles in this study led to smothering.

3.3. Univariate analysis

The univariate regression analysis showed that the number of piles was related to the time of day (0–4 h, >4–8 h, >8–12 h) and pile size was related to the area where piles started (centre of the floor area, wall). No effect of flock age and hybrid on the number of piles, pile duration and pile size were found. Spearman correlations revealed that the colony size positively correlated with pile sizes (R=0.64, p = 0.001) and did not correlate with the number of piles (R=0.3, p = 0.18) and pile durations (R=0.32, p = 0.16). The pile duration positively correlated with the pile size (R=0.67, p < 0.001).

3.4. Regression analysis of piling characteristics

The most parsimonious model linking the number of piles with the explanatory variables included the time of day (ΔAICc to second best model: 7.94, AICcWt: 0.98). The random effects variance of the full random term was 5.6. More piles occurred at > 4–8 h (model estimated mean: 0.04 piles/recorded location, CI: 0.01–0.1) compared to > 8–12 h (model estimated mean: 0.02 piles/recorded location, CI: 0.005–0.06, Tukey`s HSD, df=419, p = 0.0017) and 0–4 h after lights on (model estimated mean 0.01 piles/recorded location, CI: 0.003–0.04, Tukey`s HSD, df=419, p < 0.001). No difference was observed between > 8–12 h compared to 0–4 h (Tukey`s HSD, df=419, p = 0.39). No relationships were found between the area where piles started and the number of piles. The output of the final model is presented in Table 4.

The best model explaining pile size included the area where piles started (ΔAICc to second best model: 4.39). The random effects variance of the full random term was 0.44. The pile size was larger in the centre of the floor area (model estimated mean: 18 hens/pile, CI: 12–29) than at the barn walls (model estimated mean: ten hens/pile, CI: 6–16, Tukey's HSD, df=91, p = 0.002). No relationship was found between time of day and pile size. The output of the final model is presented in Table 5. There was no significant association between pile duration and the explanatory variables time of day and area where piles started.

3.5. Participant and interview characteristics

Participants from both farmer organisations (6 per organisation), male (9) and female participants (3), participants keeping hens on different housing systems (two aviaries, four floor systems, six mobile barn perch systems) participated in the study (Supplements, Table 2). Four participants (two per organisation) declared they had a low level of experience (two years of keeping laying hens), eight participants were classified as experienced (i.e., keeping laying hens for three or more years). The interviews lasted on average 29.14 ± 10.18 min (16:00 min - 52:00 min).

Table 5
Model summary for the most effective model of pile size. Location was included as an explanatory variable. Hybrid, colony size and flock age were treated as covariates. The random term variance was 0.44, degrees of freedom were 91, model estimates (Estimate), standard errors (SE), two-tailed t-test values (t-value), *p*-values, and 95%-confidence interval limits (CI low and CI high) are reported.

Term	Level	Estimate	SE	t-value	*p*-Value	CI low	CI high
Intercept		4.72	3.62	2.02	0.04	1.05	21.20
Location	Wall	0.39	0.12	-3.08	< 0.01	0.21	0.71
Hybrid	Lohmann	1.70	1.85	0.49	0.62	0.20	14.31
	Shaver	0.75	0.73	-0.29	0.77	0.11	5.08
Colony size		1.65	0.32	2.60	0.01	1.13	2.40
Flock age	30 weeks	0.48	0.14	-2.45	0.01	0.27	0.86

3.6. Content analysis of mechanisms leading to piling and smothering

Six categories of piling and smothering were induced that participants reported differing in preceding factors and behavioural mechanisms. More specifically, participants reported that piling and smothering are related to I) the transfer of hens from the rearing to the layer barn, II) flight responses, III) broken routines, IV) gregarious nesting in nest boxes, V) gregarious floor nesting, and VI) other gregarious behaviours in the centre of the floor area. Participants` statements were summarised below. Superscript refers to participants` quotes presented in Table 6.

I) All participants felt that the transfer from the rearing to the layer barn risks piling and smothering.[1] Hereby, considerable losses were reported to occur especially in mobile barns in the first two nights after hens arrived at the layer barns.[2a,b] Most participants reported losing hens when they gather in barn corners.[3]

II) Participants felt that piling could be induced by hens showing flight responses which could occur throughout the production period, for example, when hens become upset by unfamiliar barn equipment or staff, resulting in piling in barn corners.[4a,b] Furthermore, participants felt that hens could respond strongly to unknown salient environmental stimuli that may induce flight responses.[5a,b,c] Participants felt that hens show flight responses often at the onset of lay. Reasons reported were that at the onset of lay, sexual maturation, hormonal changes and the starting egg-laying activity increase the stress levels of laying hens, making piling behaviour and smothering due to flight responses more likely.[6a,b] Some participants also related individual bird-level differences in reactivity with higher sensitivity to frightening events and smothering.[7]

III) Participants described that piling and smothering occurred when environmental changes interrupted hens` daily routines. The interruption of routines was perceived to lead to piling and smothering at key times when hens are motivated to access specific resources. For example, broken feeders and closed exits to the outdoor area ("pop holes") were often mentioned as leading to smothering.[8a,b] One participant felt that a broken nest could lead to smothering.[9]

Table 4
Model summary for the most effective model of the number of piles. Time of day was included as an explanatory variable. Hybrid, colony size and flock age were treated as covariates. The random term variance was 5.6, degrees of freedom were 419, model estimates (Estimate), standard errors (SE), two-tailed t-test values (t-value), *p*-values, and 95%-confidence interval limits (CI low and CI high) are reported.

Term	Level	Estimate	SE	t-value	*p*-Value	CI low	CI high
Intercept		0.00	0.00	-4.89	< 0.01	0.00	0.03
Time of day	Midday	3.60	1.05	4.39	< 0.01	2.03	6.38
	Afternoon	1.53	0.51	1.29	0.20	0.80	2.94
Hybrid	Lohmann	2.40	3.16	0.67	0.50	0.18	31.51
	Shaver	2.00	2.07	0.67	0.50	0.26	15.23
Colony size		1.35	0.50	0.81	0.42	0.65	2.79
Flock age	30 weeks	0.62	0.37	-0.80	0.43	0.19	2.01

Table 6
Farmers` statements on the identified piling behaviour and smothering mechanisms on British layer flocks. The quote numbers (Q.) refer to the superscripts in the results sections of the qualitative analysis. ID`s represent farmers' ID`s that are identical with those reported in the quantitative tables, allowing linking of qualitative and quantitative results. […] indicates that a piece of the Participants` statements was excluded.

Q	Quote	ID
I	**Transfer of hens from the rearing to the layer barn**	
1	I think it's when they get (transferred to the layer barn). It's very upsetting for them to come into a new environment with different noises […] that's when I think a lot of smothering it can cause.	12
2a	The first night with the last flock, we lost 115. I hate the first night.	14
2b	We have noticed, the one thing I have noticed is that it can be quite bad just after we've transferred them from the rearing farm. So, we have had probably more instances of it happening on the sort of first or second nights of after transfer.	20
3	Sometimes, [smothering occurs] at the first night they're here. So, we have too many hens gathering in this corner usually. We've lost a few that way, but only because they haven't spread themselves out nicely. And the next night, it's usually just fine.	18
II	**Flight responses**	
4a	But then these last few days, there are a few more floor eggs. So, instead of having the blue bucket, I'm taking a white bucket in. And just that little change, in taking a different coloured bucket in to walk around to pick the floor eggs, they have been a lot more flightier with me then.	7
4b	Anything different, or anyone going in different, anyone going in with different clothes. If someone goes in with green overalls or blue overalls, they do get upset, and that's when you can push them into corners.	12
5a	Usually, we found that you see a reason for the panic smother. We had one where we had lots of snow one time, and the birds were starting coming into full lay. And there was some ice driving down the roof and hitting on the ground, and we found we had a smother after that, and I think that was related to that movement.	7
5b	The first time the fans came on […]. Obviously, that's a big fan […], and there's a lot of light and noise and everything else, it freaked the birds. But that was again a panic [smother] on the slatted area, not on the litter. That was because the fans are actually opposite the slat, so obviously, they pushed away from the scary noise and the scary side and everything that's new to them. Once they got used to it, coming on after a couple of times, it was fine.	5
5c	In the last three or four weeks, we've had aeroplanes flying over, low flying. And when we've got in the shed, we [lost hens] in corners.	12
6a	If you've got that [smothering] earlier, you'll get more of a panic smother. I think when they're all a bit more hormonal, and they're getting used to this shed. Even if we want them to come in to lay, it seems to heighten everything within it. They're more susceptible to noise; they're more aware of wagons coming in and stuff like that. If they reach maturity to lay, they just seem to be a little bit more calmer and oblivious to things, whereas once they hit that sexual maturity peak, it seems just so much more susceptible to any noise, any movement.	7
6b	The reason I relate [it, piling and smothering] to the start of lay is, at the start of lay is also when the birds are becoming more active and expressing certain behaviours. One of those behaviours is a high level of agitation normally, an increase in stress because they're working hard laying eggs which they haven't done before. Also, I presume there is a lot of hormonal activity going on inside the bird. So, their behaviour becomes challenging at that time.	17
7	I would have said flightier birds or high-strung birds will smother more because they get a little bit scared quicker.	10
III	**Broken routines**	
8a	We've had one bad smothering incident, but I think […] we had a mechanical problem with the feed line, and then once the feeders filled back up, they all piled in to get feed.	20
8b	If we didn't let them out at the same time every day, you would get smothering. If, let's say you would normally let them out at 9:00 o′clock, if you forgot or you were busy with something else, and you didn't get them let out till 10, you can guarantee that you have smothering in that shed. That's just routine. If you broke their routine and they just couldn't cope.	8
9	One of the nests flew up, so it's been removed. And the birds that have no nests have got in another nest, and I think we lost two [because of smothering] in there, two days ago.	12
IV	**Gregarious nesting in nest boxes**	
10	I would have said most of it is when they are coming into lay. […] These in the next boxes is just when they're coming into lay. Like [in] that week 19, 20, 21, 22, 23 [of bird age].	10
11	Sometimes, some nest boxes become really busy. The first one here, or the last one usually. But once I've lost a couple of hens or something, then I am ready to go and check and move them out or leave the door open at the crucial time [when they smother] in the morning, usually.	18
12	And they'll just pile on top of one end of the nest boxes. […] And we've had not lost a lot of birds like that, but maybe we lose two or three like that.	19
V	**Gregarious floor nesting**	
13	I think you can get smothering when there are floor eggs involved. We (have such) a certain corner alike. They'll get in that corner and lay eggs in that corner so you could lose them that way.	12
14a	I think they smother early in the morning from about 6:00 am onwards. The reason I say that is that when you walk in at 7:00 or 8:00 o′clock in the morning, it's obvious that the birds recently smothered, you know? They're not part cold birds. I mean, some of them are still alive because they're near the top of the pile. The ones at the bottom are suffocated, so they're dead.	17
14b	It happens just generally when there is a peak of lay in the day. It depends on what flock, what they want to be laying at. I would say that I tend to find it at the peak point of lay in the day.	11
15	We have found, if we darken the little areas, we just encourage floor eggs in the morning. […] Even if there this is a shadow and a dark spot, and they'll lay under the enrichment.	5
16	At the last three flocks, we had Bovan birds, and they were really quite bad for smothering. So, I think they are a very lazy temperamental bird. It wasn't so much they would smother; they just wouldn't move. If they all went and sat in the corner, they won't move. But the flocks, when they are Shaver, they don't seem to always do it as Bovans, I found.	11
VI	**Other gregarious floor behaviours**	
16	At the last three flocks, we had Bovan birds, and they were really quite bad for smothering. So, I think they are a very lazy temperamental bird. It wasn't so much they would smother; they just wouldn't move. If they all went and sat in the corner, they won't move. But the flocks, when they are Shaver, they don't seem to always do it as Bovans, I found.	11
17	The creeping ones, they are the ones that I just can't handle why they do it. I looked it up, but it's like they grow up in a bundle for some unknown reason.	19
18	It was the same time, 02:00 – 3:00 o′clock in the afternoon, maybe slightly later sometimes. And they just do all of that, sort of like, ganging together, heads high.	7
19a	I've generally found when they're about peak lay, is the worst, and then they settle down after that. I've never seen them carry on doing it after like 30 weeks.	10
19b	It's usually getting to about 30, 35 weeks, and I find that they tend to stop, they do tend to carry on that behaviour, but I don't tend to get these smothers.	7
20a	Yes, in a bad way, though in the opposite way that it should work. In fact, that litter quality, you want a good, deep, soft friable litter which encourages them to dustbathe and scratch about it, but what I tend to find is that there are the points where you'll get smothering. If you get a group of hens that dustbathe, and then they all start piling on top. And then, where the litter is good, it tends to be where they all congregate.	8
20b	Maybe there is quite a bit of litter on the floor, I think; what tends to happen is that birds dusting in there and then get overcome by all these birds on top. I think that is how they get smothered. Because it's not a panic smother, it's just a movement, and it's like a wave of them, isn't it?	7
21	If you get them doing that movement, that smothering around that same areas. It's […] never on really areas where it's a bit capped (hard), and the litter isn't as good.	7
22a	And then, for whatever reason, they just start creeping smothering; it's not like they are afraid, it's not they are smothering cause of laying eggs. They are just in the middle of the scratch, and they just pile on top of each other for some unknown reason. Usually, I'll find it more often when it's warm. Which is strange because you'd think they would on cold days doing that.	19
22b	I don't know why they do it, but the birds, I've noticed since it's been sunny and warm, do pile off a little bit in the fields just outside the doors.	14
23	Light as well can play a part on where they smother. I think that's possible with us where we get [light] in the late afternoon when the sun is going down. You get stranger lighting into the shed. And then that's where they sort of moved towards that light and then smother.	12

(*continued on next page*)

Table 6 (*continued*)

Q	Quote	ID
24	We predominantly use Shaver and Lohmann, and yes, two years ago, you would get a lot more smothering in Shaver than you would in Lohmann because the Lohmann were flighty. And you've got a lot more creeping smothers in the Shaver, and you would maybe get a panic smother in the Lohmann because they were a bit more flighty bird.	8

IV) Most participants described experiencing piling and smothering in nest boxes when hens nest gregariously at the onset of lay.[10] In nest boxes, farmers reported that hens pile in the morning hours. More nest box smothering incidences were reported to occur at the ends of nest rows.[11] However, overall, participants experienced that gregarious nesting in nest boxes does not often lead to large losses.[12]

V) Participants reported that gregarious nesting could precede piling and smothering on the floor area in barn corners.[13] Piling due to gregarious floor nesting was reported to occur in the morning hours, occasionally resulting in smothering. [14a,b] Participants felt that low light intensities and dark spots on the floor area increase the risk for floor nesting.[15] One participant also perceived an association between floor nesting and hybrids, with some hybrids being worse for floor nesting than others.[16]

VI) Particpants found it mysterious when hens pile together and smother in the centre of the floor area, a behaviour which farmers described as "creeping smothering".[17] Participants experiencing creeping smothering felt that it more often occurs in the afternoon.[18] Participants felt that creeping smothering peaks at the peak of lay and usually stops between 30 and 35 weeks of age.[19a,b] Participants with large housing systems perceived that creeping smothering occurs more frequently in areas with high litter quality when hens dustbathe. For example, when asked if they perceive litter quality as related to creeping smothering, participants answered that increased local litter quality could lead to increased piling and smothering.[20a,b] Supporting this impression, a few participants stated that creeping smothering does not tend to occur in areas with low litter quality, for example, where it is hard.[21] Participants felt that creeping smothering is more likely in sunny and warm environmental conditions. [22a,b] Some participants related sunlight shining on the floor area with creeping smothering.[23] Finally, most participants felt that creeping smothering is related to the hybrid. Participants thought that docile hens are at a higher risk of showing creeping smothering than agile hens.[24]

4. Discussion

The current study aimed to improve the understanding of piling behaviour by video observing events preceding piling, identifying explanatory factors of piling characteristics, and by interviewing farmers on their experiences.

4.1. Piling preceding events

Piling was observed to be preceded by hens being attracted to other hen behaviours, including hens gregarious floor nesting in barn corners, or when moving through floor areas with high animal densities, mainly synchronously dustbathing hens. In addition, farmers reported piling being preceded by hens responding to the transfer from the rearing to the layer barn, flight responses to unfamiliar stimuli, hens being disrupted in their routines on the floor area, gregarious nesting in nest boxes and on the floor, and gregarious behaviours in the centre of the floor area, such as dustbathing.

The finding that multiple events can precede piling aligns with previous studies observing multiple social motivations and interactions (Campbell et al., 2016; Winter et al., 2021) preceding piling. In addition, flight responses (Bright and Johnson, 2011; Gray et al., 2020) and gregarious nesting in nest boxes (Giersberg et al., 2019; Riber, 2012a) have been described in relation to piling. Novel findings include that piling is often preceded by floor nesting, gregarious dustbathing, the transfer from the rearing to the layer shed, and routine disruptions.

Floor nesting inducing piling was observed by video and described by farmers as taking place mostly in the morning in barn corners which is the peak laying time (Villanueva et al., 2017) that coincides with times and locations of reported smothering (Barrett et al., 2014). It could result from the preference of hens to closely join conspecifics during nesting (Appleby et al., 1984; Sherwin and Nicol, 1993). Although piling behaviour was not reported in former floor nesting studies, smaller flocks (< 20 hens, Appleby et al., 1984; Sherwin and Nicol, 1993) than in the current effort, or cage-wall separations between birds when testing nesting preferences (Appleby, 1984) may have reduced the likelihood of observing piling.

Gregarious dustbathing preceded piling mostly around midday when groups of hens moved through high densities of dustbathing conspecifics in the centre of the floor area. Piling preceded by dustbathing was associated by farmers with creeping smothering that was previously reported to take place at similar times and locations (Bright and Johnson, 2011; Herbert et al., 2021). Although a study observing creeping smothering did not associate smothering preceding piling with dustbathing, the focus of that study on animal densities rather than on specific behaviours may explain the lack of a connection (Herbert et al., 2021).

Piling preceded by hens responding to the transfer from the rearing to the layer barn and being disrupted in their routines may be explained by hens requiring time to habituate to a changed environment. For example, hens are known to form strict time and location routines in commercial environments (Gómez et al., 2022; Rufener et al., 2018). When exposed to environmental changes, hens increase the tendency to behave gregariously (Riber, 2012b) or flee from the unfamiliar stimulus (Richards et al., 2012), potentially risking high local animal densities inducing piling and smothering. In this study, farmers were greatly concerned about piling and smothering after the transfer to the layer barn and effects of environmental changes on hen behaviour. However, since video observations of this and other piling studies (Campbell et al., 2016; Winter et al., 2021) took place earliest around two weeks after hens were transferred from the rearing shed, any immediate effects related to bird transfer, including possible bird responses to unfamiliar stimuli, may have been missed.

4.2. Time of day

The video assessments revealed higher piling frequencies at midday and lower frequencies in the morning and afternoon. However, time of day was not related to pile durations or sizes. In support of that finding, farmers reported that piling preceded by gregarious behaviours in the centre of the floor area occurs more frequently around noon. However, farmers also reported piling in barn corners in the morning.

The observed peak of piling frequencies at midday and lower piling frequencies in the morning corroborates previous findings (Herbert et al., 2021; Winter et al., 2021). One explanation for diurnal variations of piling is the diurnal variation of floor-oriented behaviours preceding piling (Winter et al., 2021). For example, increased piling frequencies at midday in the centre of the floor area may be explained by hens seeking the litter for dustbathing at this time (Vestergaard, 1982). In addition, farmers and previous studies (Huber and Fölsch, 1985; Winter et al., 2021) reported that hens seek sunlight spots in the litter area that may have occurred in the investigated flocks at midday when the sun was in zenith for the observed flocks (12:15–13:15, ukweathercams, 2020).

Lower observed piling frequencies in the morning may be explained by an increase in feeding and nesting, behaviours that usually occur within the aviary systems and in nest boxes (Ballard and Biellier, 1975; Villanueva et al., 2017). Although farmers also reported increased piling frequencies in the morning in barn corners, they referred mainly to the onset of lay when peaks of floor nesting in the morning and in corners

(Appleby, 1984; Sherwin and Nicol, 1993; Villanueva et al., 2017) may increase piling risks.

4.3. Pile location

Pile size varied by location, with piles in the centre of the floor area being larger than piles along walls.

Larger pile sizes in the centre of the floor area may have resulted from hens developing behaviour preferences for specific locations. For example, farmers reported that floor areas with higher litter qualities (e.g., deep, friable litter) repeatedly attract hens. Areas with higher litter qualities could be predominantly located in the centre of the floor area, where the litter quality is higher due to protection from the draft and moisture falling through pop holes. Given that higher litter quality (Odén et al., 2002) increase dustbathing motivation, hens may form local preferences for dustbathing that result in large groups of hens gregariously dustbathing in the centre of the floor area and thereby risking large piles.

Pile sizes were smaller along barn walls which may be explained by fewer hens visiting these areas and performing gregarious behaviours there. For example, although gregarious floor nesting was observed to precede piling along barn walls, floor nesting is usually performed by only a small proportion of the flock (Appleby, 1984; Lundberg and Keeling, 1999, Villanueva et al., 2017), explaining smaller pile sizes. Alternatively, reported management measures to prevent floor nesting (e.g., electric wires) would cause hens to avoid wall areas. Finally, although wall areas were generally easily accessible by hens, they may provide less space and reduced opportunities for the formation of large piles.

4.4. Age

No association between flock age and piling characteristics was detected in the video data. However, farmers reported that events preceding piling behaviour could vary at different flock ages.

The lack of a flock age effect on piling characteristics contrasts previous findings. For example, Winter et al. (2021) found that piles in brown flocks were less frequent, longer and larger at 20 weeks compared to 30 weeks of age. Longer lasting and larger piles in brown flocks at 20 weeks was previously explained by hens using the litter area when egg-laying commences or floor resting before adapting to nests and perches (Winter et al., 2021). However, in that study, piling induced by hens seeking floor areas to lay eggs or rest may have been a more predominant issue than in this study. For example, all flocks in the previous study were housed in aviary systems which may be difficult for brown hens to access (Ali et al., 2019; Faure and Bryan Jones, 1982) and increase floor-based behaviours (Tauson et al., 1999; Winter et al., 2021). In contrast, farmers in this study mostly provided flat deck systems for which they declared experiencing few floor eggs- and floor resting problems. Also, electric fences along the walls and corners of the barn installed by farmers in this study may have discouraged hens from seeking wall areas throughout the flock cycle leading to diminished floor-based behaviours, consequent piling, and flock age effects.

An alternative explanation for absence of flock age effects on piling may be the study design which, due to pandemic restrictions induced lower number of flock visits, resulted in reduced sensitivity in detecting flock age effects on piling compared to previous efforts. For example, a previous study design allowed a within-farm comparison of flock age effects on piling characteristics (Winter et al., 2021), as flocks were visited twice during the flock cycle. However, in the current effort, flocks were visited only once during the flock cycle.

Noteworthy, farmers reported that events preceding piling could vary throughout the flock cycle. For example, farmers using mobile sheds related piling in the first couple of nights after transfer from the rearing to the layer shed with floor resting at night. Also, farmers with mobile sheds were concerned about the time around the onset of lay with floor nesting in the morning. In addition, farmers with flat deck systems expressed concerns about the peak of lay when hens often show gregarious dustbathing at midday. Finally, occasional piling and smothering was described to occur throughout the flock cycle, preceded by interrupted routines and frightening events. These findings indicate that piling may be rather dependent on the interaction of birds with their housing environment than flock age.

4.5. Study limitations

The nature of this explorative study led to some limitations. First, although we tried to balance a range of factors, including flock age, hybrids, flock sizes, this was not always possible, especially while working under pandemic conditions (COVID-19 and Avian Influenza). We have addressed these limitations in the statistics, for example by including unbalanced factors as co-variates. In addition, although we would have preferred to record all flocks with the same camera equipment, we needed to adapt to the farms` technical situation. Given that the scope of the cameras was different, this may have led to some recording differences and may have influenced the number of observed piles per farm. For the qualitative part, the number of farmers interviewed on piling behaviour and smothering was low and based on a convenience sample. Thus, a generalisation of these findings is difficult. However, despite the listed limitations, the authors hope that the presented findings may support farmers in identifying the reasons for piling behaviour and smothering on their farms.

5. Conclusion

Most piling events in British flocks were preceded by hens being attracted to the behaviour of other hens and localised high animal densities. Piling frequencies were higher around noon and the pile sizes were larger at the centre of the litter area. Farmers reported that the transfer of hens from the rearing to the layer barn, flight responses, broken routines, gregarious nesting in nest boxes, gregarious floor nesting, and gregarious behaviours in the centre of the floor area could precede piling behaviour.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank the participating farmers and farmer organisations for their outstanding effort and supporting this study. In addition, we thank the Brain Health and Behaviour Group of The Royal Veterinary College, especially Siobhan Abeysinghe, Natalie Chancellor, and Theo Demmers, for their technical support. Finally, we are very grateful for funding from the Swiss National Science Foundation [grant number: P1BEP3_191797] from Switzerland.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2022.105686.

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