Problem behaviors in adult laying hens – identifying risk factors during rearing and egg production

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ABSTRACT Feather pecking, toe pecking, cannibalism, smothering, social clumping, hens laying eggs outside the nest boxes, and reduced feather quality are examples of problem behaviors and consequences reported by egg producers. The aim of this study was to identify rearing- and production-related risk factors associated with producer-reported problem behaviors in Norwegian layer flocks. Questionnaires were distributed to 410 egg producers nationwide, and 120 producers responded to the survey (response rate 29%). After exclusion of data that did not comply with the instructions, the final dataset included 78 flocks (19%). The survey covered questions about the farm, the flock's production results, the housing environment, climate and management routines, and the behavior of the birds from 16 wk of age until the flock was euthanized at 70–80 wk of age. The individual problem behaviors were combined to generate a continuous index variable called "problem behavior", ranging from 0 (none) to 8 (all the listed problem behaviors) reported. Multilevel linear regression models were applied to evaluate associations between the index and selected risk factors during rearing and production. The primary predictor was housing system during egg production: producers with aviary flocks on average ($\pm$ standard deviation) reported 1.6 ($\pm$ 0.60) more problem behaviors compared to producers with furnished cages ($P < 0.001$). Within aviaries ($n = 40$), producers, on average reported 1.7 ($\pm$ 0.50) more problem behaviors in flocks that experienced problems with climatic conditions, compared to flocks without climatic problems ($P = 0.001$). For respondents with furnished cages ($n = 30$), on average 1.1 ($\pm$ 0.50) fewer problem behaviors were reported in farms with $\geq$ 7,500 birds compared to farms with $<$ 7,500 birds ($P = 0.027$). In conclusion, this is the first study assessing management and housing factors during the rearing and laying phase associated with problem behaviors as reported by Norwegian egg producers. As this study relied on producer reported observations, future studies are needed to investigate whether objective measurements can verify these results.

Key words: problem behavior, welfare, laying hen, rearing, production

2018 Poultry Science 97:2–16
http://dx.doi.org/10.3382/ps/pex276

INTRODUCTION

Laying hens (*Gallus gallus domesticus*) in commercial egg production are often housed in groups much larger than the stable social groups formed in the wild (Väisänen et al., 2005), and their ability to perform food search or foraging is largely dependent on the housing system (Schütz and Jensen, 2001). The egg industry has tried to adapt according to increased knowledge of laying hens' needs. The European ban on conventional battery cages implemented from 2012 is an example (European Commission, 1999). Nevertheless, feather pecking, toe pecking, cannibalism, reduced feather quality, smothering, social clumping and hens laying eggs outside the nest boxes are examples of problem behaviors or consequences of such behaviors that still cause concern (Brunberg et al., 2014). Problem behaviors are defined as behaviors that are problematic for the person reporting the behavior (Mills, 2003). According to Mills (2003), 3 categories of problem behaviors have been classified: a) behaviors that have adaptive value for the given species, but that are inconvenient for the keeper; b) behaviors that are attempts to behave in an adaptive way in an environment that does not allow for complete adaptation; and c) behaviors that express disruption of the nervous system. Eggs laid outside the nest boxes increase the labor cost for the farmer

Received May 7, 2017.
Accepted September 4, 2017.
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and are, therefore, mainly a problem for the producer. The majority of the problems reported by egg producers, however, not only result in negative economic consequences but also compromise laying hen welfare (Waiblinger et al., 2006). The causes of problem behaviors are multifactorial. Genetic predisposition (Hughes and Duncan, 1972; Rodenburg et al., 2008), early rearing conditions, e.g., environmental complexity (Janczak and Riber, 2015; Brantsæter et al., 2016a; Brantsæter et al., 2016b; Brantsæter et al., 2017), stockmanship, and management procedures, e.g., access to pecking substrate (Blokhuis and Wiepkema, 1998; Tahamtani et al., 2016), are among the influencing factors. Irrespective of the cause, problem behaviors may indicate that the birds' needs are not fulfilled and might therefore serve as indicators of suboptimal welfare.

Egg production practices differ between countries making it difficult to extrapolate findings in one country or region of the world to others. There are several different hybrids and strains of laying hens commercially available. In 2015, 70% of the layers in Norwegian egg production were Lohmann layers (Lohmann Tierzucht, 2014), and the remaining 30% were Dekalb White (Hendrix Genetics, 2014). Ninety-seven to 98% of hens used in Norwegian commercial egg production are white strains (Lohmann LSL and Dekalb White) while Lohmann Brown and ISA Brown constitute the remaining 2 to 3%. On a global scale, the health status of Norwegian layer flocks is exceptionally good, and the only vaccines administered routinely are against Marek's disease and coccidiosis (Griffiths, 2016). In addition to legislation controlled by the European Union, Norwegian producers have to conform to specific, strict national laws and regulations concerning animal welfare. As an example, beak trimming has been banned in Norway since 1974 (Frøslien, 1997) whereas internationally, although the EU will implement similar rules shortly, most flocks are still beak trimmed. Another example is that, unless the farm already had a higher number of birds when the law was founded (in 2004), the maximum farm size allowed by national legislation is 7,500 birds (Landbruks-og matdepartementet, 2004). Norwegian layer flocks are thus small compared to other European countries such as Sweden (23,000 birds per farm) (Svenska ägg, 2015) and Belgium (27,000 birds per farm) (Stadig et al., 2015). In 2015, the number of registered egg production farms nationwide with flocks $\geq$ 1,000 birds was 585 (Bagley, 2016). Furthermore, Norway is one of the few countries worldwide where the majority of adult layers are kept in loose-housed systems (European Commission, 2011; EC-CIRCABC, 2014; Landbrug og Fødevarer Erhvervsfjerkræsektionen, 2015). In Norway, the vast majority of loose-housed birds are kept in indoor multi-tier aviary systems, while only 15 (2.5%) of the 585 egg producers have single-tiered floor systems (Bagley, 2016). A single-tiered floor system has litter areas along the outer walls and an elevated slatted area with feed, water, perches, and nest boxes along the middle. The option to move between different heights provides birds in aviaries with more available space and increases environmental complexity compared to housing in single-tier systems. The aviary systems consist of aviary rows and corridors. For loose-housed systems, Norwegian legislation specifies that at least one-third of the floor (equal to 250 cm^2 per bird) should contain litter (Landbruks-og matdepartementet, 2001). The aviary corridors provide the birds with available space and litter (sawdust) where the birds can perform highly motivated behaviors such as feed searching behavior, pecking, scratching and dustbathing. The aviary rows usually have 3 tiers. Drinking nipples and food troughs run along the bottom and middle tier of the aviary row, while the top tier contains perches. Nest boxes are positioned inside the aviary rows, but the exact location of the nest boxes depend on the specific aviary design. The main differences between rearing aviaries and production aviaries are that the rearing aviaries lack nest boxes, the group size during rearing is larger, and the stocking density is higher compared to aviaries used for egg production. Also, in production aviaries the hens have access to litter at all times. However, during the first wk of rearing, the chicks are confined inside the aviary row to ensure they have easy access to the food and water in the aviary rows. In 2016, 56% of adult layers were housed in aviary systems, 39% in furnished cages and 5% of egg producing flocks were in organic systems (Karianne Fuglerud Ingerød, Norwegian Poultry Association, personal communication). However, most layer pullets in Norway (80%) are reared in aviaries (Nils Steinsland, Steinsland AS, personal communication), so a minority of the aviary-reared birds are inevitably transferred to furnished cages, rather than production aviaries at the beginning of the laying phase. Confined housing systems are either furnished cages (maximum 10 birds per cage) or colony cages (up to 100 birds per cage; Rodenburg et al., 2005). Of the 39% of egg production farms with confined housing systems in Norway, the majority keep the birds in furnished cages, with a maximum of 9 hens per cage (Bagley and Rædergård, 2016). Each furnished cage contains a nest box, a designated dustbathing area and 2 perches. Water pipes with drinking nipples run along the back wall of the cages. The feed trough runs along the front of the furnished cages. The wire mesh floor is slightly tilted to ensure eggs roll down onto the egg collection belt below the feed trough. The Norwegian legislation dictates that each hen should have access to at least 850 cm^2 of cage area (Landbruks-og matdepartementet, 2001).

During early life leaving beaks intact, access to perches and age at transfer from the rearing farm to the production farm are among the factors important for laying hen welfare (Janczak and Riber, 2015; Tahamtani et al., 2016; Brantsæter et al., 2017). Development of problem behaviors can be influenced by factors during hatching, rearing or at the egg production farm. As an example, studies investigating risk factors for reduced plumage quality in adult layer flocks, identified feather pecking during rearing as a risk factor (Zeltner et al., 2000; Bestman et al., 2009; Gilani et al., 2013; de Haas et al., 2014). Other studies report that early access to perches during the rearing period reduced both cloacal cannibalism and the prevalence of floor eggs during the production period (Gunnarsson et al., 1999). The birds are transferred from the rearing farm to the egg producer at 15 to 16 wk of age. A determining factor for the ability to cope with this potentially stressful event is the housing system during rearing. After transfer from the rearing farm, aviary-reared birds displayed more alert behavior towards an object, started laying eggs earlier (Tahamtani et al., 2014), and were less fearful 19, 21, and 23 wk of age (Brantsæter et al., 2016a; Brantsæter et al., 2016b) compared to cage-reared birds. Any cause of stress during the production period can increase the risk of problem behaviors (El-Lethey et al., 2000). Factors previously found to increase the risk of problem behaviors are fluctuating indoor climate (i.e., uneven temperature or draft (Channing et al., 2001)), lack of environmental enrichment (Zeltner et al., 2000; Tahamtani et al., 2016; Brantsæter et al., 2017), incorrect feed texture (Van Krimpen et al., 2005) and suboptimal quantity and quality of human contact (Coleman and Hemsworth, 2014). Any supplement in addition to feed and water, which encourages active, explorative or foraging behavior, is considered "environmental enrichment." Examples of environmental enrichment supplied by egg producers are empty plastic boxes, box lids, toy balls, old CDs, pecking stones (aerated concrete and calcium silicate hydrate blocks), sawdust, oyster shells, and cut up pieces of manure belts or egg belts (Brantsæter et al. 2017).

As most problem behaviors (i.e., feather pecking, cannibalism, and floor eggs) are discovered after the birds reach a certain age, these problems are primarily of concern to egg producers. The main aim of this study was to identify rearing- and production-related risk factors associated with producer-reported problem behaviors in Norwegian layer flocks.

MATERIALS AND METHODS

Study Design and Data Collection

The questionnaire was designed, constructed and distributed using the online software provided by Questback™(www.questback.com). The questionnaire was divided into 4 different parts: 1) general questions about the farm; 2) questions about the flock's production results; 3) questions about the environment, climate and management routines; and 4) questions regarding the observed behavior of the birds from arrival at the egg production farm until the flock was euthanized at 70 to 80 wk of age.

Questions were a combination of multiple-choice (some of which the respondent had to choose one option and others where it was possible to tick several options) and open-answer questions. The respondents were routed to follow-up questions relevant to their respective production system and the behaviors they reported to have observed. Respondents were instructed to reply for their current flock if the animals were over 60 wk of age or for their previous flock if their present flock was younger than 60 wk of age. If the respondent had several flocks simultaneously, he/she was asked to respond for one flock only.

E-mail addresses were acquired from egg-packing centers throughout Norway. During the design of the questionnaire, it was sent to industry advisors and a selection of egg producers for testing to ensure the quality and relevance of the questions. The survey was distributed to all the egg producers whose e-mail addresses we acquired during the data collection period (August to November 2015). Throughout the data collection period the egg producers who had not yet responded to the questionnaire were sent biweekly e-mail reminders until the questionnaire was registered as "completed" by the Questback system or the period of data collection was stopped. The questionnaire, in Norwegian, is available from the corresponding author on request.

Categorization of Explanatory and Outcome Variables

After completion of the data collection, the data were quality controlled manually in Microsoft Excel (2013) to make sure that the respondent had replied according to the instructions. Inclusion criteria were that the respondents had answered for only one flock and that the age of the given flock was minimum 60 wk of age. Open answer data had to be labeled and coded appropriately for statistical analysis. Categorization of continuous variables or merging of categories necessary for further analysis was done with utmost care to ensure that the categories were biologically relevant. For example, regarding housing system at the egg production farm, the category named "other system" included aviaries with outdoor access, organic systems, and floor systems. Because these systems differ substantially from a conventional aviary regarding the level of environmental stimuli, it was considered better to keep them separate from the "aviary" group.

The outcomes included in the questionnaire were feather pecking (gentle and severe), toe pecking, cannibalism, social clumping, hysteria/panic, floor eggs and feather quality. The definitions given to the producers in the questionnaire are listed in Table 1. Before data management, the outcomes were coded as binomial variables (0 = behavior not reported; vs. 1 = behavior reported by respondent). Feather quality was also categorized as a binomial variable, where 0 = good plumage quality at $\geq$ 60 wk of age; vs. 1 = reduced plumage quality at $\geq$ 60 wk of age reported by respondent. A continuous outcome index variable was generated to avoid multiple testing of 8 different outcome variables against a large number of explanatory variables. The first step in creating the index was to

Table 1. An overview of outcomes included in the questionnaire and the information the producers were provided to answer the questions. The raw data is presented as the number (%) of respondents (N = 78) reporting the given behavior in their most recent flock ≥ 60 wk of age.

Behaviors included in the questionnaire	Description available to the producers when responding to the questionnaire	Number (%) of respondents who reported the given behavior
Gentle feather pecking	Gentle pecking at, or removal of feathers from own plumage or from a conspecific	41 (53%)
Severe feather pecking	More intense pecking at conspecific which causes skin lesions	40 (51%)
Toe pecking	Pecking at their own toes with resulting skin lesions	14 (18%)
Cannibalism	Pecking at conspecific resulting in big lesions in the skin, profuse bleeding, dysfunctional/removed body parts or death	21 (27%)
Social clumping	Some, or all, the hens pile up for no apparent reason. The birds do not seem disturbed or frightened.	27 (35%)
Hysteria/panic	Some, or all, of the hens abruptly, and for no obvious reason run or fly to one end of the room. The animals appear frightened.	19 (24%)
Floor eggs	Eggs laid outside the designated nest boxes	47 (60%)
Feather quality around the time of euthanasia	1) The hens were fully covered with good quality feathers	18 (23%)
	2) The hens had small patches without feathers	36 (46%)
	3) The hens were more or less naked	24 (31%)

tabulate the outcome variables by each explanatory variable. The tabulation was conducted to evaluate whether any outcome variables were not reported by the respondents and should therefore not be included in the index.

Statistical Analysis

All statistical analyses were conducted using Stata SE 14 (StataCorp LP); P-values ≤ 0.05 were considered statistically significant. In the first step of model building, all explanatory variables were screened individually to assess their association with the index variable. The screening was conducted by multilevel mixed-effects linear regression, with rearing farmer as a random effect. Only explanatory factors with $P < 0.2$ were kept for step 2 which was backward stepwise selection. Log likelihood tests were used to assess the overall significance of categorical variables with more than 2 levels.

The final model, also with rearing farmer as a random effect, was selected based on backward stepwise selection. Only factors with $P < 0.1$ were retained in the final model. The final model was tested to ensure it conformed to the assumptions of linear regression (normality of residuals and homogeneity of variance) by inspection of the Q-Q plot and by the Shapiro-Wilk test and by plotting standardized residuals versus fitted values. Results from the models are presented as β coefficient ± standard error.

Based on the results from the whole dataset, a decision was made to analyze subsets for each housing category, i.e., aviary systems and furnished cages. The models for these subsets were constructed according to the same procedure as described for the dataset as a whole.

RESULTS

Study Population

The response rate achieved in our study was 29% (n = 120/410). However, after exclusion of replies that did not conform to the inclusion criteria, the final dataset included 78/410 respondents (19%). The 78 flocks were located in 17 out of 19 Norwegian counties, ranging from one to 19 respondents per county. Fourteen (18%) of the respondents replied for flocks with less than 7,500 birds, whereas 64 (82%) flocks contained at least 7,500 birds. Both of the major egg-laying hybrids in Norway were represented: 55 respondents (71%) had Lohmann layers, and 23 egg producers (29%) had Dekalb White. No producers had ISA Brown layers and only 4 of 78 producers reported that they kept Lohmann Brown layers. However, these producers had mixed flocks of Lohmann Brown and Lohmann LSL and the proportions of white versus brown birds in these flocks was not recorded. The final dataset included flocks delivered by 13 of 16 possible rearing farmers nationwide, whereby each rearing farmer contributed with one to 14 flocks. Fifty (64%) of the 78 flocks were reared in aviaries, 15 (19%) of the flocks were reared in cages, and for the remaining 13 (17%) of the flocks, the rearing conditions were unknown.

The distribution of the problem behavior index per housing system is presented in Figure 1. Due to the low number of observations (n = 8), and the heterogeneity of the flocks grouped as "other system," this group was not analyzed further, but separate models were built for the aviary producers (n = 40) and furnished cage producers (n = 30).

The 40 respondents with aviary housing systems were located in 16 of the 19 Norwegian counties. Eleven different rearing farmers were represented, each contributing with one to 8 flocks. The 30 respondents with furnished cage systems represented egg producers from 11 out of the 19 Norwegian counties. Nine different rearing farmers were represented, each contributing with one to 7 flocks. The number and percentage of aviary and furnished cage respondents within each of the explanatory variable levels used to investigate the association with reported problem behaviors are shown in Tables 2A-D.

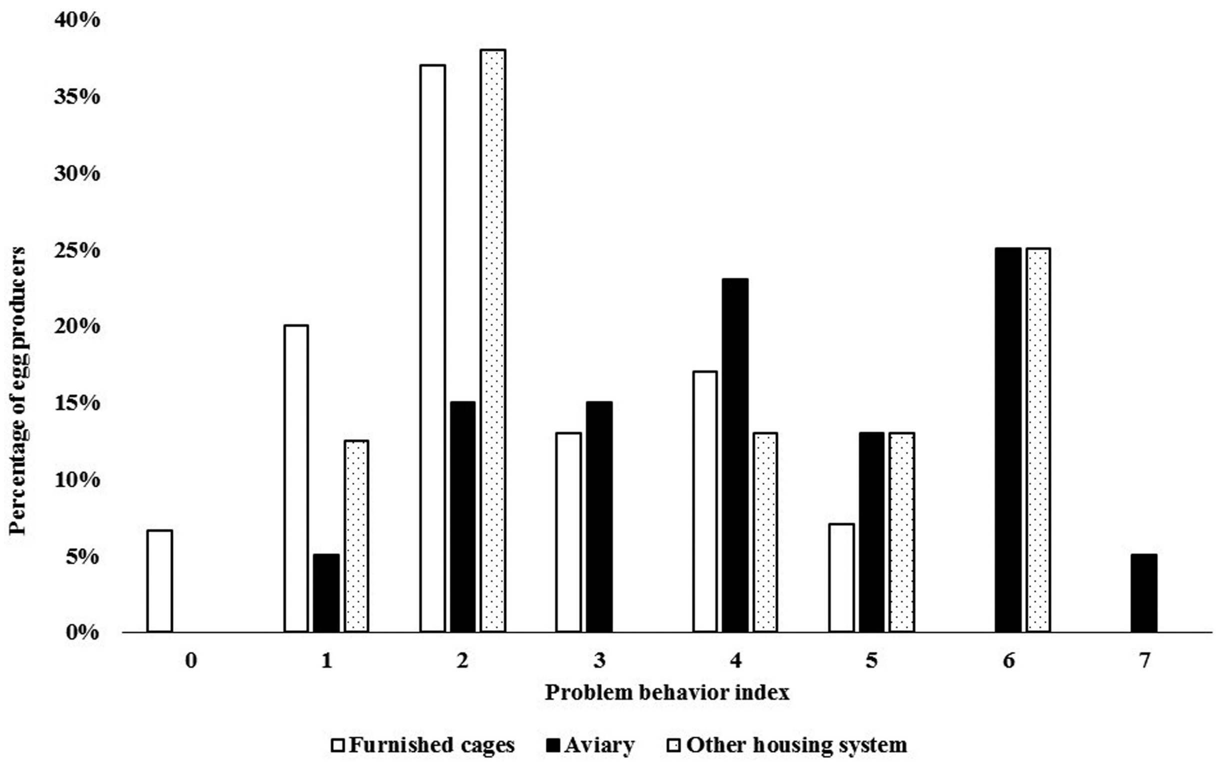

Figure 1. Overview of the percentage of reported problem behaviors grouped by housing system at the egg production farm (n = 78). Black bars = aviary; white bars = furnished cages; dotted bars = other housing system (floor systems, aviaries with outdoor access or organic production). The continuous index ranges from 0 (none of the problem behaviors reported) to 8 (all the outcomes reported) by the producer.

Table 2A. Number of aviary (AV) and furnished cage (FC) respondents grouped by rearing-related explanatory variables.

	AV respondents		FC respondents	
Rearing related variables	Number	Percentage	Number	Percentage
All data	40	100%	30	100%
Rearing housing				
Rearing cages	0	0%	15	50%
Aviary rearing	39	98%	5	17%
Don't know/other system	1	2%	10	33%
Hybrid				
Lohmann White or Brown	31	78%	18	60%
Dekalb White	9	22%	12	40%
Age of transfer to producer				
< 16 wk of age	10	25%	7	24%
16 wk of age	24	60%	19	66%
> 16 wk of age	6	15%	3	10%

AV = aviary; FC = furnished cages.

Data Management and Multilevel Linear Regression Models

In the final dataset (n = 78) all the behavioral outcomes were reported by at least 14 respondents (Table 1). The generated behavior index thus included all 8 behaviors and ranged from 0 (none of the behaviors) to 8 (all the problem behaviors) reported by each respondent. The frequency of each outcome variable, grouped by each predictor is presented in the supplementary material (Tables S1 to 8). The explanatory variables associated with the index variable ($P < 0.2$; highlighted as bold in the Table 3A-D) were included when starting the backward stepwise reduction of the multilevel linear regression model for the final dataset. Two factors were related to the rearing period and 9 factors related to the egg production farm (Table 3A-D).

Full Model

After backward stepwise reduction where only explanatory variables with $P < 0.1$ were retained, the final model for the behavior index contained housing at production farm (furnished cages compared to aviaries), challenges with climatic conditions at the production farm (yes/no) and hybrid (Lohmann LSL versus Dekalb

Table 2B. Number of aviary (AV) and furnished cage (FC) respondents grouped by explanatory variables related to the egg production farm.

Production farm related variables	AV respondents Number	AV respondents Percentage	FC respondents Number	FC respondents Percentage
All data	40	100%	30	100%
Experience with egg production				
< 7 years	19	48%	7	23%
≥ 7 years	21	52%	23	77%
Size of the flock				
< 7,500 birds	5	12%	6	20%
≥ 7,500 birds	35	88%	24	80%
Challenges with climatic conditions during production				
No	28	70%	24	80%
Yes	12	30%	6	20%
Challenges related to content or distribution of feed				
No	27	68%	22	73%
Yes	13	32%	8	27%
Light intensity adjusted using a LUX-meter				
Yes	25	62%	21	70%
No	15	38%	9	30%
Number of birds per furnished cage				
≤ 10 birds	–	–	24	80%
> 10 birds	–	–	6	20%

AV = aviary; FC = furnished cages.

Table 2C. Number of aviary (AV) and furnished cage (FC) respondents grouped by explanatory variables related to the inspection routines at the egg production farm.

Production farm inspection related variables	AV respondents Number	AV respondents Percentage	FC respondents Number	FC respondents Percentage
All data	40	100%	30	100%
Number of stockpeople				
1 to 2 people	17	42%	12	40%
≥ 3 people	23	58%	18	60%
Inspections soon after delivery to producer				
1 to 2 times per d	11	28%	12	40%
3 times per d	13	32%	10	33%
≥ 4 times per d	16	40%	8	27%
Inspections around onset of lay				
1 to 2 times per d	18	45%	22	73%
≥ 3 times per d	22	55%	8	27%
Inspections after peak of lay				
1 time per d	7	18%	6	20%
2 times per d	25	62%	22	73%
≥ 3 times per d	8	20%	2	7%
Inspection time soon after delivery to producer				
< 1 h per d	19	48%	20	67%
1 to 2 h per d	15	38%	7	23%
> 2 h per d	6	14%	3	10%
Inspection time around onset of lay				
< 1 h per d	25	62%	22	73%
> 1 h per d	15	38%	8	27%
Inspection time per d later in production				
< 30 min per d	11	28%	8	27%
30 to 60 min per d	22	55%	16	53%
> 60 min per d	7	17%	6	20%

AV = aviary; FC = furnished cages.

White). The frequency of producer-reported problem behaviors was higher in aviaries compared to furnished cages (β coefficient ± standard error; 1.61 ± 0.36; $P \leq 0.001$) and was greater if the birds had been exposed to problems with climatic conditions during lay (1.24 ± 0.38; $P = 0.001$). Also, there was a tendency for fewer reported problem behaviors among the respondents with Dekalb layers compared to Lohmann layers (−0.65 ± 0.37; $P = 0.083$). No variation was explained by the random effect rearing farmer ($P = 1.00$). The assumptions of linear regression were fulfilled.

Aviary Model

After backward stepwise removal of explanatory factors with $P > 0.1$ (Table 4), the best model for the subset of aviary flocks (n = 40) included only the variable "challenges with climatic conditions" (yes/no). The direction of effect was the same as for the dataset as a whole; flocks with reported problems with climatic conditions during lay scored higher on the index variable, suggesting more problem behavior, compared to flocks that did not experience problems related to

Table 2D. Number of aviary (AV) and furnished cage (FC) respondents grouped by explanatory variables related to use of environmental enrichment at the egg production farm.

Production farm related variables	AV respondents Number	AV respondents Percentage	FC respondents Number	FC respondents Percentage
All data	40	100%	30	100%
Access to environmental enrichment (edible and non-edible)				
Yes	38	95%	29	97%
No	2	5%	1	3%
Use of enrichment excluding shell sand and pebbles for the gizzard				
Yes	32	80%	25	83%
No	8	20%	5	17%
Types of edible enrichment the birds are given access to				
None	4	10%	4	13%
One type	12	30%	16	53%
Two types	12	30%	10	33%
> 2 types	12	30%	0	0%
Types of non-edible environmental enrichment the birds are provided				
None	9	23%	28	93%
One type	12	30%	2	7%
≥ 2 types	19	47%	0	0%
Substrate used as dustbathing material				
Saw dust	–	–	14	47%
Other	–	–	16	53%
Access to the dust bathing area before onset of lay				
Yes	–	–	18	60%
No	–	–	12	40%
Provision of dust bathing material occurs				
≥ 1 per wk	–	–	11	37%
Less regularly than weekly	–	–	19	63%

AV = aviary; FC = furnished cages.

Table 3A. Number of observations, mean score (SD) and *P*-value for between-level comparisons for problem behavior for each level of all factors related to the rearing phase.

Rearing related variables	Number of respondents	Problem behavior index (values 0 to 8) Mean (SD)	*P*-value
Rearing housing	78		
Rearing cages	15	2.13 (0.99)	ref.
Aviary rearing	50	3.88 (1.80)	**≤ 0.001**
Other rearing system/don't know	13	3 (1.83)	**0.164**
Hybrid	78		
Lohmann White or Brown	55	3.62 (1.74)	ref.
Dekalb White	23	2.87 (1.87)	**0.085**
Age of transfer to producer	77		
< 16 wk of age	18	3.17 (1.82)	ref.
16 wk of age	48	3.54 (1.83)	0.448
> 16 wk of age	11	3.18 (1.78)	0.982

Tables 3A-D. The number of observations, mean index score (standard deviation) and *P*-value for between-level comparisons for each level of each factor included in the questionnaire (N = 78). Values for the index variable range from 0 to 8. The *P*-values are the result of multilevel linear regression models with rearing farmer as random effect with individual screening of the explanatory variables. Variables with *P*-values < 0.2 (highlighted in bold) were included in backward stepwise reduction. The levels for each explanatory variable used as reference category are marked as "ref".

climatic conditions (1.70 ± 0.50; $P = 0.001$). No variation was explained by the random effect rearing farmer ($P = 0.21$). The assumptions of linear regression were fulfilled.

Furnished Cage Model

After backward stepwise removal of explanatory factors with $P > 0.1$ (Table 5) the best model for the furnished cage subset (n = 30) included number of animals at the farm (< 7,500 versus ≥ 7,500 birds) and use of a LUX-meter to control the light intensity in the hen house (yes/no). The results indicate that more problem behavior was reported in farms with less than 7,500 birds compared to farms with at least 7,500 birds (-1.42 ± 0.51; $P < 0.01$). Also, there was a tendency for lower risk of observing problem behaviors among the respondents who used a LUX-meter to adjust the light intensity (-0.82 ± 0.45; $P = 0.07$). No variation was explained by the random effect rearing farmer ($P = 0.16$). The assumptions of linear regression were fulfilled.

DISCUSSION

Summary of Main Findings

The aim of this study was to identify rearing- and production-related risk factors associated with producer-reported problem behaviors in Norwegian layer flocks. As all the 8 outcomes included in the survey

Table 3B. Number of observations, mean score (SD) and *P*-value for between-level comparisons for problem behavior for each level of all factors related to the production phase.

Egg production farm variables	Number of respondents	Problem behavior index (values 0 to 8) Mean (SD)	*P*-value
Experience with egg production	78		
< 7 years	28	3.57 (1.87)	ref
≥ 7 years	50	3.30 (1.76)	0.518
Production housing system	78		
Furnished cages	30	2.33 (1.35)	ref.
Aviary	40	4.18 (1.68)	**< 0.001**
Other housing system	8	3.50 (2.00)	**0.061**
Size of the flock	78		
< 7,500 birds	14	3.5 (1.51)	ref.
≥ 7,500 birds	64	3.38 (1.86)	0.812
Challenges with climatic conditions during production	78		
No	56	3.04 (1.67)	ref.
Yes	22	4.32 (1.81)	**0.003**
Challenges related to feed or feed distribution during production	78		
No	56	3.36 (1.69)	ref.
Yes	22	3.5 (2.09)	0.75
Is light intensity in the production house set using a LUX-meter	78		
Yes	51	3.18 (1.79)	**0.127**
No	27	3.81 (1.78)	ref.

Tables 3A-D. The number of observations, mean index score (standard deviation) and P-value for between-level comparisons for each level of each factor included in the questionnaire (N = 78). Values for the index variable range from 0 to 8. The P-values are the result of multilevel linear regression models with rearing farmer as random effect with individual screening of the explanatory variables. Variables with P-values < 0.2 (highlighted in bold) were included in backward stepwise reduction. The levels for each explanatory variable used as reference category are marked as "ref".

Table 3C. Number of observations, mean score (SD) and *P*-value for between-level comparisons for problem behavior for each level of all factors related to inspection at the egg production farm.

Inspection variables at egg production farm	Number of observations (n)	Problem behavior index mean (SD)	*P*-value
Number of stockpeople	78		
1 to 2 people	33	3.45 (1.58)	ref.
≥ 3 people	45	3.33 (1.95)	0.711
Inspections soon after delivery to producer	78		
1 to 2 times per d	24	2.92 (1.80)	ref.
3 times per d	24	3.63 (1.79)	**0.162**
≥ 4 times per d	30	3.60 (1.80)	**0.155**
Inspections around onset of lay	78		
1 to 2 times per d	42	3.00 (1.55)	ref.
≥ 3 times per d	36	3.90 (1.97)	**0.029**
Inspections after peak of lay	78		
1 time per d	13	3.23 (1.64)	ref.
2 times per d	54	3.22 (1.76)	0.987
≥ 3 times per d	11	4.45 (1.97)	**0.085**
Inspection time soon after delivery to producer	78		
< 1 h per d	41	3.10 (1.81)	ref.
1 to 2 h per d	23	3.78 (1.57)	**0.134**
> 2 h per d	14	3.64 (2.06)	0.316
Inspection time around onset of lay	78		
< 1 h per d	49	3.24 (1.61)	ref.
≥ 1 h per d	29	3.66 (2.07)	0.324
Inspection time per d later in production	78		
< 30 min per d	21	3.24 (1.64)	ref.
30 to 60 min per d	41	3.44 (1.87)	0.674
> 60 min per d	16	3.5 (1.90)	0.658

Tables 3A-D. The number of observations, mean index score (standard deviation) and P-value for between-level comparisons for each level of each factor included in the questionnaire (N = 78). Values for the index variable range from 0 to 8. The P-values are the result of multilevel linear regression models with rearing farmer as random effect with individual screening of the explanatory variables. Variables with P-values < 0.2 (highlighted in bold) were included in backward stepwise reduction. The levels for each explanatory variable used as reference category are marked as "ref".

were reported, a continuous index variable was created. Overall, egg producers with aviary systems reported more problem behaviors compared with furnished cage producers. Additionally, issues with climatic control during lay were associated with increased observation of problem behaviors. There was a tendency for the producers with Dekalb layers to report fewer problem behaviors compared to the producers with Lohmann layers. The main risk factor associated with observing more problem behaviors in aviary systems was issues with climatic control during lay. For furnished cages, producers with smaller farms reported more problem

Table 3D. Number of observations, mean score (SD) and P-value for between-level comparisons for problem behavior for each level of all factors related to administration of environmental enrichment at the egg production farm.

Environmental enrichment at egg production farm	Number of observations (n)	Problem behavior index mean (SD)	P-value
Access to environmental enrichment (edible and non-edible)	78		
Yes	75	3.45 (1.78)	**0.162**
No	3	2.00 (2.00)	ref.
Use of enrichment excluding shell sand and pebbles for the gizzard	78		
Yes	63	3.43 (1.81)	0.752
No	15	3.23 (1.80)	ref.
Types of edible enrichment the birds are given access to	78		
None	8	2.88 (1.73)	**0.133**
One type	30	3.13 (1.87)	**0.102**
Two types	23	3.48 (1.56)	0.35
> 2 types	17	4 (1.97)	ref.
Types of non-edible environmental enrichment the birds are provided	78		
None	42	2.79 (1.57)	**≤ 0.001**
One type	14	3.57 (1.83)	**0.114**
≥ 2 types	22	4.45 (1.74)	ref.

Tables 3A-D. The number of observations, mean index score (standard deviation) and P-value for between-level comparisons for each level of each factor included in the questionnaire (N = 78). Values for the index variable range from 0 to 8. The P-values are the result of multilevel linear regression models with rearing farmer as random effect with individual screening of the explanatory variables. Variables with P-values < 0.2 (highlighted in bold) were included in backward stepwise reduction. The levels for each explanatory variable used as reference category are marked as "ref".

Table 4. Overview of the 5 explanatory variables with $P < 0.2$ that were relevant to include in analysis for the aviary (AV) flocks (n = 40). Mean and standard deviation (SD) are described for each level.

Explanatory variables (AV)	Number of observations	Problem behavior index mean (SD)	P-value
Challenges with climatic conditions during production			
No	28	3.68 (1.59)	ref.
Yes	12	5.33 (1.30)	0.001
Inspection time around onset of lay			
< 1 h per d	25	3.84 (1.60)	ref.
> 1 h per d	15	4.73 (1.71)	0.085
Inspection time per d later in production			
< 30 min per d	11	3.45 (1.63)	ref.
30 to 60 min per d	22	4.41 (1.68)	0.097
> 60 min per d	7	4.57 (1.62)	0.135
Types of non-edible environmental enrichment			
None	9	3.44 (1.74)	0.053
One type	12	3.92 (1.73)	0.186
≥ 2 types	19	4.68 (1.53)	ref.
Number of inspections after peak of lay[1]			
1 time per d	7	4.14 (1.57)	ref.
2 times per d	25	3.8 (1.68)	0.602
≥ 3 times per d	8	5.38 (1.30)	0.122

[1]The variable had only one level with $P < 0.2$. Log likelihood test (LR $chi^2 = 5.82$; Prob > $chi^2 = 0.0546$) indicated that the variable should be included in the model prior to backward stepwise reduction.

Table 5. Overview of the explanatory variables with $P < 0.2$ that were relevant to include in analysis for the flocks housed in furnished cages (FC) (n = 30). Means and standard deviations (SD) are described for each level.

Explanatory variables (FC)	Number of observations	Problem behavior index mean (SD)	P-value
Size of the flock			
< 7,500 birds	6	3.33 (1.03)	ref.
≥ 7,500 birds	24	2.08 (1.32)	0.012
Challenges related to content or distribution of feed			
No	22	2.55 (1.34)	ref.
Yes	8	1.75 (1.28)	0.067
Light intensity adjusted using a LUX-meter			
Yes	21	2.14 (1.31)	0.172
No	9	2.78 (1.40)	ref.
Inspection time around onset of lay			
< 1 h per d	22	2.5 (1.26)	ref.
≥ 1 h per d	8	1.88 (1.55)	0.05
Access to environmental enrichment (edible and non-edible)[1]			
Yes	29	2.41 (1.30)	0.044
No	1	1 (-)	ref.

[1]Only one producer did not provide the birds with any sort of environmental enrichment, so this variable had to be excluded from further analysis.

behaviors compared to larger farms, while those who used a LUX-meter to adjust the light intensity in the hen house tended to observe fewer problem behaviors.

Risk Factors Related to the Production Phase

Housing System A key finding in our study was that aviary producers reported more problem behaviors than the furnished cage producers did. Loose-house systems enable birds to express more behaviors compared to birds in confined housing (reviewed by (Lay et al., 2011)). Most of the behavioral problems reported in this study, except eggs laid outside the nest boxes, are behaviors that are also observed in wild jungle fowl. However, the consequences of these behavioral responses might differ for birds kept in commercial housing conditions compared to animals living in the wild. As an example, fear-related responses (e.g., the birds' responses when faced with predators) can increase the chance of survival in the wild. On the contrary, commercial housing conditions may not allow the birds to avoid the fear-inducing stimuli, and fear-responses might even result in injuries or suffocation if the birds fly/run into the metal constructions or pile on top of each other (Jones, 1996). This example illustrates how behavioral responses with adaptive value in the wild can compromise animal welfare and the farmer's economy in commercial egg production (Mills, 2003). Birds in aviaries have the possibility to express more behaviors than birds in furnished cages. Hence, it will also be easier for aviary birds to perform some of the problem behaviors (e.g., laying eggs in the litter rather than in the designated nest boxes) than for cage-housed birds. Our results indicate that this aspect of Norwegian egg production is comparable to results from studies conducted in other countries, where aviaries are also associated with higher proportions of problem behaviors compared to furnished cages (Rodenburg et al., 2005; Tauson et al., 2006; Sherwin et al., 2010; Shimmura et al., 2010; Lay et al., 2011; Stadig et al., 2016). Animal welfare, conceptualized as a continuous scale from poor to good, is secured when the animal is healthy, experiences positive rather than negative affective states and is able to express innate behaviors (Fraser et al., 1997). Thus, without additional measures of welfare, caution should be exercised when using the current study to argue that one housing system might be better for animal welfare than another.

Our finding of more problem behaviors reported in the aviaries compared to the furnished cages might reflect the actual situation. However, the results could be explained by the limitations of the data collection method (questionnaire) (see paragraph under methodological considerations). Furthermore, egg producers with furnished cage systems might be different from aviary egg producers regarding their motivation to focus on these problems, their level of awareness or possibility to detect these problem behaviors. For instance, if eggs are laid outside a nest box in a furnished cage, the tilted floor will allow the egg to end up at the egg belt without increased labor of the farmer. Regarding assessment of toe pecking, feather pecking or plumage quality, the location of the furnished cage (top, bottom, or low tier) might influence the farmers' ability to physically assess the feathers while walking through the house (Tablante et al., 2000; Brantsæter et al., 2016a). Similarly, assessment of the birds perching on the top tier of the aviary might be a challenge for aviary producers.

Issues with Climatic Conditions

Our results of the association between climatic conditions and more problem behaviors reported by the aviary respondents add support to existing knowledge. Among the aviary producers who described problems controlling the climatic conditions in the henhouse, issues with maintaining stable and optimal temperatures, uneven temperature in different parts of the house and draft were most commonly reported. A possible explanation for the association between climatic conditions and increased risk of problem behaviors can be the altered stocking density when uneven temperatures cause birds to cluster in some parts of the house and avoid other areas. The effect of distorted stocking density in loose-housed systems is not entirely understood as some, but not all studies report increased risk of aggression and reduced feather quality with increased stocking density (Gunnarsson et al., 1999; Gunnarsson et al., 2000; Channing et al., 2001; Nicol et al., 2006; Collins et al., 2011; Widowski et al., 2016). Clustering should be taken seriously, as it affects the birds' thermoregulatory abilities (Green and Xin, 2009), and heat stress has been demonstrated to cause immunosuppression in adult layers (Mashaly et al., 2004).

Besides, in areas with clustering, or reduced ventilation, there can be "blind spots" with build-up of gasses such as ammonia and carbon dioxide. As exposure to these gasses is uncomfortable, they possibly reduce the time the stockperson spends in the hen house. Ammonia exposure can cause health problems not only among the animals but also be negative for the stockpeople (Kirkhorn and Schenker, 2002; Kirychuk et al., 2003; Xin et al., 2011; David et al., 2015a; David et al., 2015b). In laying hen houses with confined cage systems, researchers concluded that areas with low ventilation were more common in corners and along the back of the house, posing a potentially bigger problem for the stockpeople than the animals (Prodanov et al., 2016). In comparison, in loose-housed systems, where the birds have access to the areas with potentially increased concentration of harmful gasses, this is a greater concern regarding animal welfare. On the contrary, as opposed to loose-housed hens, birds kept in cages are not able to avoid areas of suboptimal climatic conditions. In other words, issues with climatic conditions might affect loose-housed birds and birds housed in confined cages differently.

Management and Stockmanship Differences between Aviary and Furnished Cage Producers

The association between issues with climatic control and increased occurrence of problem behaviors as perceived by the egg producers might be real. However, from our study, we cannot exclude the possibility that climatic control is a reflection of the general management. The result that use of a LUX-meter tended to be associated with a decrease of reported problem behavior among furnished cage producers could be another indication of management differences between the aviary and furnished cage producers. Loose-housing systems are considered more challenging to manage, and demand a better stockmanship compared to confined housing systems (see review (Appleby and Hughes, 1991; Häne et al., 2000)). The effect of the stockpeople can therefore be of greater importance for loose-housed birds compared to cage-housed birds. The majority of the respondents never exceeded 1 h of daily inspections, regardless of whether the birds had recently arrived at the farm or were around the age of the onset of lay (Table 3C). Towards the end of the production phase, most of the respondents spent less than 30 min inside the house. The aviary producers inspected the birds more often, compared to the furnished cage producers during the onset of lay as well as later in the production cycle (Table 3C). However, from our data is it not possible to distinguish what came first, the problem behaviors and therefore a need for more frequent inspections, or whether the more frequent inspections allowed the aviary respondents to detect the problems better than the furnished cage producers. Furthermore, lack of positive interaction with a human can be a cause of fearfulness and stress in laying hens (Edwards et al., 2013). In our study, no direct measures of the quality of farmer-animal interactions or fearfulness were obtained, so the bird's association of human presence as a positive or negative event is unknown. Fearfulness is associated with several of the outcomes covered by the questionnaire, specifically feather pecking (Uitdehaag et al., 2009; de Haas et al., 2010; de Haas et al., 2013; Kops et al., 2013; Rodenburg et al., 2013), cannibalism (Newberry, 2004) and smothering (Bright and Johnson, 2011; Barrett et al., 2014). If the animals in our study associated the farmer with a negative event (i.e., danger), the increased number of inspections might have been among the causative factors for the increased occurrence of problem behaviors perceived by the aviary respondents. In our study, furnished cage producers reported less problem behavior in farms with $\geq$ 7,500 birds compared to farms with $<$ 7,500 birds (Table 5). As the time the farmer spent inspecting the birds was a maximum of 30 to 60 min irrespective of the number of birds per cage, we cannot rule out the possibility that the egg producer to a larger degree overlooked problem behaviors or consequences of such behaviors in farms with more birds. Another possible explanation for this association is that a bigger farm could reflect a more dedicated and professional producer compared to a small farm. Fifty of the 78 (64%) producers had at least 7 years of experience with egg production. As the maximum number of birds per farm has been 7,500 since 2004, it is unlikely that lack of experience is confounded with the effect of flock size. Future studies are required to assess the potential confounding effect of management associated with the identified risk factors.

Genetics as a Risk Factor

Hybrid was included as an explanatory variable in the linear regression model for the whole dataset (Table 3A). There was a tendency (P = 0.083) for fewer observed problem behaviors among Dekalb producers compared to Lohmann producers. To a certain extent, this supports anecdotal evidence from egg producers who have the impression that Lohmann layers more often struggle with feather pecking and reduced feather quality compared to Dekalb layers (Brunberg et al., 2014). On the other hand, Dekalb producers more often consider floor eggs to be a problem. Although White and Brown layer strains have been found to differ concerning fearfulness (Uitdehaag et al., 2011), propensity to feather peck and develop cannibalistic behavior (Kjaer and Sorensen, 2002), the authors are not aware of studies focusing on differences in problem behaviors between Lohmann and Dekalb layers. Future studies are needed to test whether the tendency detected in our study is replicable in an observational study, as the finding based on our questionnaire also could be caused by subjective bias (see paragraph under methodological considerations).

Rearing-Related Risk Factors

Thirteen of the 78 egg producers (17%) did not know if their flock was reared in confined or loose-housed systems (Table 3A). The majority of the producers that did not know the rearing conditions of their birds had furnished cage systems (Table 2A). Possible explanations are that furnished cage producers are not as familiar with the different housing systems rearing farmers can utilize during rearing, there may be lack of knowledge of the effect of rearing under different conditions, or they may trust the rearing farmer with the decision. From this, one could question whether producers with furnished cages do not have the same interest, or perceived need to be informed, about rearing effects, as producers with aviary systems. Rearing farmer was included in the multilevel linear regression models as a random effect to deal with the fact that flocks from the same rearing farmer may be more similar than flocks from different rearing farmers. However, rearing farmer was not identified as a source of variation in the full model, the aviary subset or the furnished cage subset.

Methodological Considerations

The primary methodological consideration of this study is the possible systematic error introduced because the data relies on producer-perceived information. The producer is an unmeasurable confounder (Dohoo, 2014) as he or she both affects the exposure (i.e., management of the flock) and the outcome (i.e., is the one who reported the behaviors). Furthermore, the questionnaire is sensitive to information bias (e.g., recall bias, misinterpretation of the questions or different opinions of the provided definitions of the behaviors) (Dohoo, 2014). This study was retrospective relying on respondents' memory or written records. Depending on the age of their current flock, some respondents may have had to recall from up to a year back. The data collected does not provide information about whether replies were based on objective measures or subjective impressions (e.g., of levels of ammonia). Finally, we cannot rule out the possibility of selection bias due to non-response bias (Dohoo, 2014), as we did not follow up the non-responders to see whether their replies would have differed from responders. Non-response bias can contribute to higher reports of problem behaviors, as producers without experience with these issues might have lacked the motivation to complete the questionnaire. Non-response bias could also result in under-reporting of these problems if producers experiencing these problems did not reply to the questionnaire.

Validity

The aim of the current study was to assess risk factors, rather than detect the prevalence of problem behaviors. Estimating prevalence would have required a different study design based on random selection of egg producers. The following paragraph therefore focuses on limitations in the assessment of the risk factors identified in the current study. Generalization of the findings is discussed regarding internal validity (i.e., if the results are representative of the source population) and external validity (i.e., if the results are valid for the target population).

Internal Validity

Selection bias arises when the study group (sample) is not representative of the source population (Dohoo, 2014). The behavioral problems covered by the survey usually are not present in young birds. The exclusion of flocks aged < 60 wk was necessary to ensure that the flocks were comparable. Whether this exclusion of 42 flocks introduced selection bias is unknown. It cannot be ruled out that farmers replying for flocks < 60 wk, did so because they did not understand the instructions or were different from farmers who did understand the instructions of the questionnaire and replied for flocks of minimum 60 wk of age.

External Validity

The total number of e-mail addresses we obtained (source population) was 410 (out of 585 registered egg producers (target population)). The reduction of e-mail addresses was due to egg-packing centers (rather than producers) not willing to cooperate, so the source population is thus unlikely to differ from the target population (all Norwegian egg producers). The response rate of 29% is acceptable for a rather lengthy questionnaire relying on response through an electronic system (reviewed by Sheehan, 2001). The final dataset represents nearly all the Norwegian counties, the majority of the rearing farmers and the 2 commercial hybrids. Additionally, the proportion of respondents with aviaries and furnished cage systems were close to the numbers registered by the industry (Karianne Fuglerud Ingerød, Norwegian Poultry Association, personal communication).

As mentioned in the introduction, some aspects of the Norwegian egg industry are markedly different from other countries (i.e., smaller farm size, small cage units, no beak trimming and the majority of birds are loose-housed). As the risk factors identified in the current study were essentially management related, their effect under different farm sizes is difficult to predict. Furthermore, management regimes at larger farms may be qualitatively different from management at smaller farms. The results of the current study should therefore be interpreted with caution when extrapolating to other countries. However, as the genetic material is the same for all who import Lohmann or Dekalb layers, our findings may be of relevance to others using these breeds for egg production. Particularly with the impending ban on beak trimming, the results of this study could be valuable to egg producers in Europe to make them aware of potential risk factors.

CONCLUSION

To our knowledge, this is the first time the producer perceived occurrence of problem behaviors is investigated in Norwegian egg production. All the 8 outcomes covered by the questionnaire (gentle feather pecking, severe feather pecking, toe pecking, cannibalism, social clumping, mislaid eggs, and reduced plumage quality) were reported by 18 to 60% of egg producers. The main factors associated with increased risk of observation of problem behaviors in our survey were problems with climatic conditions and the housing system during lay. For respondents with furnished cages, the main predictor was the size of the farm: more problem behaviors were reported in smaller farms compared to bigger farms. Future studies investigating the causal relationships between rearing and production related risk factors and problem behaviors are warranted and should include objective measures of climatic conditions as well as behavioral observations by trained observers.

ACKNOWLEDGMENTS

This work was funded by the Norwegian Levy on Agricultural Products (FFL), the Agricultural Agreement Research Fund of Norway (JA), and Animalia (Norwegian Meat and Poultry Research Center) through the Research Council of Norway, grant number 207739. We would like to thank all rearing and production producers who participated in the study.

There was no need for approval from an ethical committee for conducting this survey as it was purely observational and did not involve any biological manipulation of the birds.

AUTHOR CONTRIBUTIONS

MB participated in the design of the questionnaire, contacted producers, collected the data, manually controlled the raw data, performed data analysis and drafted the manuscript. JN assisted in the statistical analysis and drafted the manuscript. TBH participated in the design of the questionnaire, contacted the egg-packing centers, contacted producers, assisted in the manual control of the raw data and drafted the manuscript. KM participated in the design of the questionnaire, assisted with data analysis and drafted the manuscript. AN assisted in data analysis and drafted the manuscript. ROM participated in the conceptualization and design of the study and drafted the manuscript. AMJ led the project, participated in the conceptualization and design of the study, participated in the design of the questionnaire, and drafted the manuscript. All authors accepted the final version of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors of this manuscript have declared that no competing interests exist. Animalia (Norwegian Meat and Poultry Research Center) contributed with funding for the project and the author TBH is employed by Animalia. She contributed as described under author contributions. Animalia finances and performs applied agricultural research in collaboration with the private and public sectors. Animalia's sole interest in the present study was to support publication of the unbiased results in order to provide advice to poultry rearing farmers and egg producers. The financial contribution by Animalia does not alter the authors' adherence to Poultry Science policies on sharing data and materials.

SUPPLEMENTARY DATA

Supplementary data are available at *Poultry Science* online.

Table S1. Rearing farmer variables relative to behavior outcomes. Number (N) and percentage of respondents within each level is shown.

Table S2. Production farm variables relative to reported behavior outcomes. Number (N) and percentage of respondents within each level is shown.

Table S3. Producer inspection routines relative to behavior outcomes. Number (N) and percentage of respondents within each level is shown.

Table S4. Producer environmental enrichment management relative to the behavior outcomes. Number (N) and percentage of respondents within each level is shown.

Table S5. Rearing farmer variables relative to feather quality after 60 wk of age. Number (N) and percentage of respondents within each feather quality category is shown.

Table S6. Production farmer variables relative to feather quality after 60 wk of age. Number (N) and percentage of respondents within each feather quality category is shown.

Table S7. Production farmer inspection variables relative to feather quality after 60 wk of age. Number (N) and percentage of respondents within each feather quality category is shown.

Table S8. Environmental enrichment management relative to feather quality after 60 wk of age. Number (N) of respondents and percentage within each feather quality category is shown.

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