Heritability of Feather Pecking and Open-Field Response of Laying Hens at Two Different Ages

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ABSTRACT The objective of the current study was to estimate heritabilities (h^2) of feather pecking and open-field response of laying hens at two different ages. An F_2 cross, originating from a high and a low feather pecking line of laying hens, was used for the experiment. Each of the 630 birds of the F_2 cross was subjected to an open-field test (individual, 10 min) at 5 and 29 wk of age and to a social feather pecking test (groups of five birds on wood shavings, 30 min) at 6 and 30 wk of age. Both tests were performed in a square open field (1.25 × 1.25 m). Behavior was recorded directly from a monitor. Heritabilities of feather pecking and open-field behaviors were calculated. In the open-field test at 5 wk of age, high h^2 were found for most traits, ranging from 0.20 for the frequency of flying to 0.49 for number of steps. In the social test at 6 wk, gentle feather pecking (0.12) and ground pecking (0.13) were found to be heritable. When both tests were repeated at 29 and 30 wk of age, h^2 estimates were lower for the open-field test, ranging from 0.10 for duration of sitting to 0.20 for latency to first step. In the social test, however, higher h^2 estimates of 0.15 for gentle feather pecking and 0.30 for ground pecking were found compared with 6 wk of age. In conclusion, gentle feather pecking and open-field behaviors may be used in selection against feather pecking.

(*Key words*: behavior genetics, feather pecking, heritability, laying hen, open field)

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INTRODUCTION

Feather pecking impairs animal welfare and results in higher feeding costs and increased mortality rates in laying hens. It is characterized by pecking at and pulling of feathers of other birds. Feather removal has been shown to be painful (Gentle and Hunter, 1990), and results in bald patches. This feather damage as a result of feather pecking can lead to a heat loss resulting in 20% higher energy requirements (Blokhuis and Wiepkema, 1998). The bald patches may attract tissue pecking, resulting in wounded birds that may be pecked to death (Savory, 1995). Feather pecking is a problem in all current housing systems for laying hens, but in large group housing systems the problem is more difficult to control. Current changes in the European Union from beak-trimmed birds in battery cages toward large group housing with birds with intact beaks require tools to control feather pecking. In the United States, guidelines developed by large fast-food chains in cooperation with scientists (Rahn, 2001) may steer future egg production systems in the same direction as in the European Union.

Line differences in plumage condition (Ambrosen and Petersen, 1997; Wahlstrom et al., 2001) and in feather-pecking behavior (Hughes and Duncan, 1972) suggest a genetic background. Direct selection has been shown to be feasible, using individual selection against feather pecking (Kjaer et al., 2001) or group selection against mortality (Craig and Muir, 1993; Muir, 1996). Craig and Muir (1993) reported a high realized family heritability (h^2) of 0.65 for days without beak-inflicted injuries. Three studies have reported h^2 of feather pecking based on direct observations of pecking behavior (Cuthbertson, 1980; Bessei, 1984; Kjaer and Sørensen, 1997). In these studies, h^2 for performing feather pecking ranged from 0.07 to 0.56 and for receiving feather pecking from 0.00 to 0.15. None of these studies distinguished between the different forms of feather pecking, i.e., gentle and severe feather pecking (Savory, 1995). This distinction may be important, as gentle and severe feather pecking may have different ways of developing and may be affected differently by genetic and environmental factors. Recently, it has been suggested that gentle feather pecking at young

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Abbreviation Key: h^2 = heritability.

age may develop into stereotyped gentle feather pecking or into severe feather pecking in adult laying hens caused by increased intensity or increased severity of bird-to-bird pecks (McAdie and Keeling, 2002).

Feather pecking has also been associated with fearfulness (Hughes and Duncan, 1972) and, more recently, with open-field response (Jones et al., 1995) and coping strategy (Korte et al., 1997). The open-field test has been used for the study of emotional reactivity and motivation in laboratory animals but also in poultry (Candland and Nagy, 1969). Gallup and Suarez (1980) proposed that open-field behavior in poultry is a compromise between opposing tendencies in a bird to return to its flock mates and to minimize detection by predators (experimenter). Some studies have estimated h^2 for open-field behaviors, with estimates for overall locomotion ranging from 0.08 to 0.49 and for defecation from 0.06 to 0.10 (Boyer et al., 1970; Faure, 1981; Webster and Hurnik, 1989). Jones et al. (1995) showed that birds from a low feather-pecking line vocalized and walked earlier in an open field than birds from a high feather-pecking line, reflecting differences in social motivation to return to their flock mates. Thus the open-field response may be useful as a predictor of feather-pecking behavior and the open-field test may be used to select against feather pecking.

The aim of the present experiment was to estimate h^2 of open-field response at 5 and 29 wk of age and of feather pecking at 6 and 30 wk of age. A distinction was made between gentle and severe feather pecking, as they may be affected differently by genetic and environmental factors. The current study may give a better understanding of the possibilities to select against feather pecking either by direct observation of feather pecking or by selection on related characteristics using the open-field test. This research may eventually enable the breeding of birds that are better adapted to future housing systems.

MATERIALS AND METHODS

Genetic Stock and Population Structure

Two selection lines from a commercial breeder were used for this experiment. These lines have been selected for production-related traits but also differ consistently in feather-pecking behavior, i.e., high and low feather-pecking lines (Rodenburg and Koene, 2001; Riedstra and Groothuis, 2002; Van Hierden et al., 2002). A reciprocal cross of these lines was made: six high feather-pecking males and six low feather-pecking females were used to produce the high × low cross, and six low feather pecking males and six high feather pecking females were used to produce the low × high cross. These crosses resulted in an F_1 generation consisting of 120 chickens. From this generation, seven males and 28 females were randomly selected and mated to produce an F_2 generation. On average, each female produced 23 female offspring, and each male produced 90 female offspring. The total number of female chickens in the F_2 generation was 630.

TABLE 1. Ethogram of the open-field test

Behavior	Description
Sitting	Sitting with breast and belly on the floor
Standing	Standing, feet or legs, but not belly, on the floor
Walking	Locomotion, minimum of 2 steps
Step	Number of steps
Flying	Flapping wings, no contact with floor
Distress call[1]	Distress call (peep)
Alarm call[2]	Alarm call (kot kot kot kodeeek)
Alarm call note[2]	Alarm call note (kot)
Defecating	Defecating

[1]Only included in the ethogram at 5 wk of age.
[2]Only included in the ethogram at 29 wk of age.

Housing and Management

Birds arrived at the experimental farm as 1-d-old chicks in five batches. Every 2 wk, a batch of about 125 chicks was delivered (wk 30, 32, 34, 36, and 38 in the year 2000). Each batch was allocated at random to two floor pens with an average of 63 birds (between 55 and 70) in each pen, 10 pens in total. Each pen was 4.75 × 2 m and was supplied with wood shavings, two heating lamps per pen for warming, and ad libitum feed (152 g/kg crude protein, 2.817 kcalME/kg) and water. From 0 to 4 wk of age, the birds had continuous light (one red heating lamp and two 40-W light tubes per pen). From 5 through 15 wk of age, the heating lamps were removed, and the birds had 8 h light between 0800 and 1600 h. From 16 wk of age onward, the light period was extended by 1 h/wk, until birds had 16 h light between 0300 and 1900 h at 24 wk of age.

The birds were not beak-trimmed. Each bird was individually marked with a wing tag. Males not excluded from the experiment at 1 d of age, due to errors in gender determination, were removed at 5 wk of age. At 18 wk of age, each pen was supplied with laying nests and perches. During the experiment, the mortality rate was 13%, partly because of a coccidiosis infection when the birds were about 20 wk of age. This infection mostly affected batches 4 and 5, resulting in more space per bird for these groups. All groups were treated with vitamins, and after that treatment no problems with coccidiosis were observed. The Wageningen University Committee on Animal Care and Use approved this experiment.

Open-Field Test

At 5 and 29 wk of age, all birds were tested individually in the open-field test for 10 min. The open field consisted of a 1.25 × 1.25 m observation pen, which was divided into 25 squares by white markings (5 × 5), measuring 25 × 25 cm each. The front wall was made of Perspex, through which a camera recorded the area of the pen. The observer could then record the behavior from a video screen in an adjacent room. General activity and vocalizations were recorded according to the ethogram (Table 1). Latencies, durations, and frequencies of all common behaviors were recorded using focal sampling.

TABLE 2. Ethogram of the social test

Behavior	Description
Gentle feather peck	Gentle feather peck, no reaction receiver, and neck still
Gentle bout	Bout of gentle feather pecks
Severe feather peck	Severe feather peck, reaction receiver, neck moves
Severe bout	Bout of severe feather pecks
Aggressive peck	Dominance peck, directed at head, neck, or back
Ground bout	Bout of ground pecks. Pecks directed at ground

The catching procedure consisted of entering the home pen, passing a number of birds, walking back to the door, and capturing the first bird in sight, alternating between the two groups of one batch. To avoid unnecessary stress of an individual before the test, it was transported to the observation pen in a box and was placed in the middle of the observation pen. The room with the observation pen was dark until the start of the test. At 5 wk of age, the same person conducted all behavioral observations, but a different experimenter tested and handled batch 2. At 29 wk of age, two different persons performed the open-field observations after their behavioral recording methods were brought into conformity with each other.

Birds were tested between 0845 and 1615 h. After the test, each bird was marked with a color across the back (just behind the neck) for identification purposes in the social test. For this purpose, five different colors (red, green, blue, purple, and orange) were alternated. Earlier observations showed that these colors did not affect feather pecking behavior or aggressive interactions (T. B. Rodenburg, unpublished data).

Social Test

At 6 and 30 wk of age, all birds were tested in groups of five in the social test for 30 min; this test was described previously by Rodenburg and Koene (2001). The social test was executed in the open-field observation pen with wood shavings on the floor. Five birds with different colors were captured from one pen of a batch, alternating between the two pens. Birds were identified and transported to the observation pen in a crate, where they were placed in darkness. The test began with switching on the light. After 5 min, a sound signal was produced to avoid birds being inactive for 30 min. Body weight of each bird was recorded after the test, and birds were marked with a black dot. One person handled and observed all birds in the social test. The birds were all tested between 0845 and 1545 h. Pecking behavior was sampled directly using behavior sampling, i.e., sampling all occurrences of some behaviors (Martin and Bateson, 1993). For feather pecking and aggressive pecking, the actor and the receiver were recorded. The ethogram is described in Table 2.

Statistical Analyses

Exploratory analyses were performed with SAS software (SAS Institute, 1996) by use of the general linear model procedure to estimate sire and dam variances. For analysis of the open-field test, sire (seven levels) and dam (28 levels; nested within sire) were included in the model as random effects, whereas pen (10 levels) and time of testing (five levels at 5 wk and four levels at 29 wk) were included as fixed effects. The social test was analyzed with sire (seven levels) and dam (28 levels; nested within sire) included in the model as random effects and test group (129 levels at 6 wk and 112 levels at 30 wk) included as the fixed effect. Body weight was analyzed in a separate model, including the effects of pen (10 levels) and day (three levels). Variances were estimated based on information of sire and dam components of variance. Heritability estimates based on the sire component and the dam component, respectively, were then calculated as

$$h^2_{SIRE} = 4\ \sigma^2_{SIRE}/\sigma^2_P \text{ and } h^2_{DAM} = 4\ \sigma^2_{DAM}/\sigma^2_P.$$

Subsequently an analysis was performed using an animal model and the ASREML software package (Gilmour et al., 2000). Univariate analyses were performed on all recorded traits to estimate the phenotypic and additive genetic variance. For this analysis, the following mixed model was used:

$$Y = X\beta + Zu + e$$

where Y is a vector of observations, X is the design matrix for fixed effects, β is the vector of fixed effects, Z is the design matrix for random effects, u is the random effects with var (u) = $A\sigma^2_u$, and e is the residual with var (e) = $I\sigma^2_e$. The fixed effects for the open-field test were pen with 10 levels and time of testing with five levels at 5 wk of age and four levels at 29 wk of age. The fixed effect for the social test was test group with 129 levels at 6 wk of age and 112 levels at 30 wk of age. The fixed effects for both tests were the same as used for the exploratory analysis with SAS software (SAS Institute, 1996).

RESULTS

Description of Traits

Means and standard deviations of indicator traits in the open-field test and in the social test at both ages are presented in Table 3. In the open-field test at 5 wk of age, birds on average spent 430 s sitting (72% of total time). If birds became active, they started to vocalize, and then they stood up and walked. On average, they uttered about 56 distress calls and walked 30 steps. Some birds also

TABLE 3. Means and standard deviations of indicator traits in the open-field test at 5 and 29 wk of age and in the social test at 6 wk and 30 wk of age

	5 wk		29 wk	
Trait	Mean	SD	Mean	SD
Open-field test				
Duration of sitting (s)	431	201	209	252
Duration of standing (s)	134	163	357	241
Latency to first call[1] (s)	334	230	467	191
Latency to stand up (s)	424	205	190	252
Latency to first step (s)	460	184	496	157
Number of steps	30	52	10	25
Number of calls	56	67	34	81
Number of defecations	0.6	1.0	0.7	0.8
Frequency of flying	0.3	0.8	0.03	0.2
Social test	6 wk		30 wk	
Number of gentle bouts	0.6	1.3	0.8	1.5
Number of gentle pecks	1.4	3.9	1.5	3.6
Number of severe bouts	0.04	0.29	0.3	0.9
Number of severe pecks	0.09	1.02	0.5	1.5
Number of ground bouts	4.1	5.4	7.3	6.3
Number of aggressive pecks	0.00	0.00	0.14	0.04
Body weight (g)	368	56	1,606	154

[1]Distress call at 5 wk of age, alarm call at 29 wk of age.

tried to fly out of the open field (mean 0.27 flights per bird). At 29 wk of age, birds spent less time sitting (35% of total time) and walking (10 steps) and more time standing (60% vs. 22% of total time) than at 5 wk of age. In the social test, incidents of gentle and severe feather pecking and ground pecking were more frequent at 30 wk than at 6 wk of age. Average BW increased from 368 g at 6 wk to 1,606 g at 30 wk. Most distributions of behavioral traits were skewed to the right with many observations with value zero.

Heritabilities

Heritability estimates for open-field behaviors at 5 wk of age were high (Table 4). They ranged from 0.20 for the frequency of flying to 0.49 for number of steps. For number of defecations, h^2 was 0.22. In the social test at 6 wk of age, only gentle feather pecking (0.12) and ground pecking (0.13) were found to be heritable behavioral traits. Heritability estimates for severe feather pecking and aggressive pecking and for receiving gentle and severe feather pecking and aggressive pecking were not significantly different from zero. For BW, a h^2 of 0.40 was found. When h^2 were estimated based on sire or dam variances, h^2 estimates based on the dam component of variance were generally lower than those based on the sire component.

At 29 wk of age, h^2 estimates for behaviors measured in the open-field test were lower than at 5 wk of age, ranging from 0.10 for duration of sitting to 0.20 for latency to first step (Table 5). Heritability estimates of duration of standing, latency to stand up, number of calls, and frequency of flying were not significantly different from zero. In the social test, h^2 were higher compared with 6 wk of age. For gentle feather pecking bouts, a h^2 estimate of 0.15 was found, for gentle pecks an estimate of 0.16, and for ground pecking an estimate of 0.30. Also at 30 wk of age, h^2 estimates for severe feather pecking and aggressive pecking and for receiving gentle and severe feather pecking and aggressive pecking were not significantly different from zero. Comparable with the results from 5 and 6 wk of age, h^2 estimates based on the dam component of variance were generally lower than those based on the sire component when h^2 were estimated based on either sire or dam variances.

DISCUSSION

The aim of the current experiment was to estimate h^2 of feather pecking and open-field response in young and adult birds. High h^2 were found for open-field behaviors at 5 wk of age. In the social test at 6 wk of age, gentle feather pecking and ground pecking were found to be heritable. At 29 wk of age, h^2 of open-field behaviors were lower than at 5 wk of age. For gentle feather pecking and ground pecking, higher h^2 were found at 30 wk of age compared with 6 wk of age. The h^2 of severe feather pecking was not significantly different from zero at either age.

Heritability Estimates

In the present study h^2 were estimated in an F_2 population. This may affect the estimates, as the variation in the F_1 population is the mean of variation within the original lines (Lande, 1981). If the lines to make the cross had been inbred strains, the variance between families would be zero. Although inbred strains were not used in the current study, population structure might have affected the estimates. Also the distributions of the traits have to be taken into account. Most distributions of behavioral traits were skewed to the right with many observations with value zero.

TABLE 4. Heritability (h^2) estimates with standard errors and sire- and dam-based estimates of indicator traits in the open-field test at 5 wk and in the social test at 6 wk of age

Trait	h^2	SE	h^2_{SIRE}	h^2_{DAM}
Open-field test				
Duration of sitting	0.38*	0.12	0.48	0.26
Duration of standing	0.27*	0.11	0.29	0.20
Latency to first call	0.38*	0.13	0.43	0.23
Latency to stand up	0.35*	0.12	0.46	0.22
Latency to first step	0.45*	0.13	0.58	0.29
Number of steps	0.49*	0.13	0.54	0.45
Number of calls	0.32*	0.11	0.61	0.09
Number of defecations	0.22*	0.09	0.32	0.11
Frequency of flying	0.20*	0.09	0.14	0.19
Social test				
Number of gentle bouts	0.12*	0.07	0.21	0.03
Number of gentle pecks	0.08	0.06	0.14	0.00[1]
Number of severe bouts	0.00	0.02	0.00	0.00
Number of severe pecks	0.02	0.04	0.00[1]	0.05
Number of aggressive pecks	0.02	0.03	0.00	0.00
Number of ground bouts	0.13*	0.07	0.21	0.08
Receiving gentle bouts	0.00	0.00	0.00[1]	0.09
Receiving severe bouts	0.00	0.04	0.00	0.00
Receiving aggressive pecks	0.01	0.03	0.00	0.00
Body weight	0.40*	0.13	0.17	0.34

[1]Estimated sire or dam variance component was negative.

*h^2 significantly different from zero.

When h^2 were estimated based on transformed frequencies (square root transformation) and latencies (log transformation), however, estimates were comparable with the estimates based on the nontransformed data, whereas the distribution of the transformed traits was closer to a relatively normal distribution. Finally, the number of animals used in this experiment was limited compared with studies in which h^2 for production traits were estimated. For a behavioral study, however, the current study with 630 individual birds was large, and the number of studies on populations of this size is limited, which is mainly due to the labor intensity of behavioral observations at individual level.

Heritabilities Open-Field Test

At 5 wk of age, h^2 for locomotion traits in the open-field were high. The h^2 of 0.49 for number of steps is in close agreement with the h^2 reported by Boyer et al. (1970) for overall movement. The estimated h^2 for number of defecations of 0.22 is higher than those reported by Boyer et al. (1970) and Faure (1981) of 0.06 and 0.10, respectively.

TABLE 5. Heritability (h^2) estimates with standard errors and sire- and dam-based estimates of indicator traits in the open-field test at 29 wk and in the social test at 30 wk of age

Trait	h^2	SE	h^2_{SIRE}	h^2_{DAM}
Open-field test				
Duration of sitting	0.10*	0.06	0.23	0.05
Duration of standing	0.08	0.05	0.23	0.03
Latency to first call	0.18*	0.09	0.43	0.09
Latency to stand up	0.07	0.05	0.11	0.08
Latency to first step	0.20*	0.09	0.28	0.18
Number of steps	0.15*	0.08	0.09	0.21
Number of calls	0.09	0.06	0.19	0.00
Number of defecations	0.16*	0.08	0.22	0.11
Frequency of flying	0.04	0.04	0.03	0.05
Social test				
Number of gentle bouts	0.15*	0.08	0.27	0.14
Number of gentle pecks	0.16*	0.08	0.23	0.19
Number of severe bouts	0.06	0.05	0.07	0.02
Number of severe pecks	0.07	0.05	0.09	0.07
Number of aggressive pecks	0.01	0.03	0.05	0.00[1]
Number of ground bouts	0.30*	0.20	0.28	0.20
Receiving gentle bouts	0.04	0.06	0.00[1]	0.19
Receiving severe bouts	0.00	0.03	0.00	0.00
Receiving aggressive pecks	0.03	0.04	0.06	0.00[1]
Body weight	0.50*	0.14	0.75	0.35

[1]Estimated sire or dam variance component was negative.

*h^2 significantly different from zero.

At 29 wk of age, h^2 for open-field behaviors were much lower than at 5 wk of age, consistent with the value obtained by Webster and Hurnik (1989) in 17-wk-old pullets. Most of the open-field tests in poultry have been performed with young chicks (Boyer et al., 1970; Gallup and Suarez, 1980; Faure, 1981; Jones et al., 1995). In chicks, the motivation to return to their flock mates is strong, as is their fear of being detected by predators. In adult laying hens, these motivations may be less strong, as they seem to be more important to young and vulnerable birds.

Heritabilities Social Test

In the social test at 6 and 30 wk of age, only gentle feather pecking, ground pecking, and BW were found to be heritable traits, with higher h^2 at 30 wk of age. Kjaer and Sørensen (1997) also found higher h^2 for feather pecking at 38 wk of age compared with 6 wk of age. The h^2 estimates for gentle feather pecking of 0.12 at 6 wk of age and 0.15 at 30 wk of age fit well with the estimates for total feather pecking in previous studies (Cuthbertson, 1980; Bessei, 1984; Kjaer and Sørensen, 1997). The h^2 of severe feather pecking was not significantly different from zero at both ages. At 6 wk of age, only 14 of 630 birds performed severe feather pecking so the low incidence may be part of the explanation. At 30 wk of age, however, the incidence was higher, and yet the same result was found. This result indicates that, under the conditions used in this experiment, the development of severe feather pecking depends mainly on a combination of environmental factors and not as much on genetic factors. In previous studies, no distinction was made between gentle and severe feather pecking, but the present results indicate that it may useful to separate them, as they seem to be controlled by different mechanisms.

Heritabilities of receiving gentle or severe feather pecks or aggressive pecks were not significantly different from zero in the present study. In the case of receiving severe feather pecking or aggressive pecking, the low incidence may play a role. Kjaer and Sørensen (1997) found a low h^2 (0.15 ± 0.07) for receiving feather pecking at 6 wk of age.

Sire- and Dam-Based Heritabilities

When h^2 were estimated based on sire or dam variances, in most cases the sire-based estimates were considerably higher than the dam-based estimates. These results were contrary to expectations, because any presence of dominance and maternal effects would be included in the dam component of variance. Maternal genetic effects have, for instance, been shown to affect BW and ascites-related traits in broilers (Pakdel et al., 2002). In the present study, the h^2 estimate for BW based on the dam variance is higher than the estimate based on the sire variance at 6 wk of age but lower at 30 wk of age. The standard errors of the estimates of the sire- and dam-based h^2 were higher than those of the ASREML estimates, which may also explain the apparent differences in sire- and dam-based h^2. Genetic causes may provide an alternative explanation, with possible explanations being sex linkage or parent-of-origin effects. It was not possible to investigate these possibilities with the available data.

In conclusion, gentle feather pecking and open-field response were found to be heritable, which may offer the possibility for genetic selection against feather pecking in the future. For open-field behaviors, h^2 were higher at 5 wk of age compared with 29 wk of age. For gentle feather pecking, ground pecking, and body weight measured in the social test, h^2 were higher at 30 wk of age than at 6 wk of age. The h^2 estimate for severe feather pecking was not significantly different from zero at either age. In further research, the relationships between feather pecking and open-field response will be studied to identify possible predictors of feather pecking, supplying tools to select against feather pecking.

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