Europ.Poult.Sci., 79. 2015, ISSN 1612-9199, © Verlag Eugen Ulmer, Stuttgart. DOI: 10.1399/eps.2015.84

Europ.Poult.Sci., **79.** 2015, ISSN 1612-9199, © Verlag Eugen Ulmer, Stuttgart. DOI: 10.1399/eps.2015.84

The phenotypic interrelationships between feather pecking, being feather pecked, feather eating, feather score, fear, body weight, and egg production traits in a F2- cross of White Leghorn lines selected for high and low severe feather pecking

Phänotypische Beziehungen zwischen Federpicken, Bepicktwerden, Federfressen, Gefiederzustand, Furcht, Körpergewicht und Legeleistungsmerkmalen in einer F2- Kreuzung von Weißen Leghorn Linien, die auf hohes und niedriges Federpicken selektiert wurden

Stefanie Bögelein[1], **J.B. Kjaer**[2], **J. Bennewitz**[1] and **W. Bessei**[1]

[1] Dept. of Population Genomics, Inst. of Animal Science, University of Hohenheim, Stuttgart, Germany

[2] Inst. for Animal Welfare and Animal Husbandry, Friedrich-Loeffler-Institute, Celle, Germany

Correspondence: bessei@uni-hohenheim.de

Manuscript received 10 July 2014, accepted 10 December 2014

Introduction

Feather pecking and cannibalism are very important behavioural problems in laying hens. Apart from bird welfare, feather pecking has an economical impact. Birds with poor feather cover balance their heat loss through higher feed consumption. This usually results in a poor feed conversion ratio (FCR) (Emmans and Charles, 1977; Tauson and Svensson, 1980; Damme and Pirchner, 1984; Grashorn and Flock, 1987; Biedermann et al., 1993). However, the relationships between feathering and production traits are more complex. Hughes (1980) and Tullet et al. (1980) reported that hens with poor plumage condition increased their egg production. This increase may partially compensate the negative effect of poor feather cover on feed conversion rate. Hagger et al. (1989) found even a better feed conversion rate in poorly feathered hens. The opposite effect of poor feathering on egg production has been reported by Peguri and Coon (1993). Removal of the feather cover in White Leghorn hens reduced egg production at low and normal ambient temperature (12.8°C and 23.9°C). Only at high ambient temperature (33.9°C) the egg production of defeathered hens was higher compared to fully feathered hens.

Severe feather pecking is causing most of the feather damage in domestic fowl as well as in Red Jungle Fowl (Vestergaard et al., 1993). Therefore the assessment of plumage condition using feather scoring has been used as an alternative to behavioural observations (Hughes and Duncan, 1972; Tauson, 1984; Grashorn and Flock, 1987).

It has been shown that feather eating is closely related to feather pecking and feather damages (McKeegan and Savory, 1999; Harlander-Matauschek and Bessei, 2005; Ramadan and von Borell, 2008). Harlander-Matauschek et al. (2006) developed a feather eating test, where individually housed hens are offered feathers fixed on a plastic element. Hens selected for high feather pecking (HFP) under group housing conditions consumed consistently more feathers in the feather eating test than hens selected for low feather pecking (LFP) (Häusler, 2008, Bögelein et al., 2010). Therefore the feather eating test has been considered as a method to identify feather pecking hens.

Relationships between feather pecking and fear have been reported in many studies. Groups of hens with high feather damage were found to be more fearful (Hughes and Duncan, 1972; Choudary et al., 1972; Hughes and Black, 1974; Bessei, 1980; Bilčík and Keeling, 1999; Kjaer, 2000; Hocking et al., 2001). Cuthbertson (1978) mentioned that fearful birds represent the feather pecking birds while less fearful birds represent the birds being pecked. According to Jones et al. (1995) and Buitenhuis et al. (2005) high levels of fear are related to feather pecking. De Haas (2014) suggested fear as a major cause of feather pecking in layer lines and their parent stocks. The relationship between fear and feather damages, however, differed in response to the method fear was assessed. This was confirmed by Bögelein et al. (2014).The relationship between fear and feather pecking was further complicated by the age of the birds at the fear tests application. In the present study only the "approach" or "pencil" test in adult birds was included. This test has been developed by HUGHES and DUNCAN (1972) and was used in various experiments (SEFTON and CROBER, 1976; BESSEI, 1980). The pencil test as fear criterion has been chosen for the present study for different reasons: i) in previous experiments this test has proved a high repeatability, ii) it is being carried out in the home cage, e.g. there is no influence of transport to the test room and iii) it is conducted at the same time as the performance data recording.

Most studies on relationships of feather pecking, fear and production in laying hens have been carried out on the basis of group means. This is the first time that criteria related to feather pecking, fear and performance have been recorded on a large number of individual birds. In addition the use of F2-crosses of lines which have been selected for high and low feather pecking represent an excellent bases for the study of the correlations between the criteria.

While in a preceding study (BÖGELEIN et al., 2014) feather pecking and fear have been assessed in relation to other behaviours, the aim of the present study was to investigate the relationships of feather pecking and fear with feather eating, laying performance, body weight, and feather score.

The University of Hohenheim Committee on Animal Care and Use approved these experiments with the numbers S266/10, S335/12 and S338/12.

Material and methods

Housing conditions

The birds used in the present experiment stem from a F2- cross of two lines of White Leghorn selected for high (HFP) and low (LFP) number of bouts of severe feather pecking for 10 generations. The design of the F2-crosses has been described in detail by BENNEWITZ et al. (2014). Briefly, an equal number of dams and sires of the HFP and LFP lines of the 10th selection generation (genetic selection criteria, see KJAER et al., 2001) were reciprocally mated in order to produce 10 F1-families. One male of each family was mated to 8 hens of the other families. A total of 967 female F2 birds were produced in 4 successive hatches (280, 255, 250 and 182 birds per hatch). Due to mortality and loss of identification tags the number of birds used for statistical analyses decreased slightly with age.

The chicks were sexed, vaccinated against Marek's disease and neck-banded at day-old. All chicks were randomly assigned to pens measuring 1.20 m × 0.90 m of 10 birds each. At 3 weeks of age all birds of the same hatch were transferred to larger deep litter pens (2.6 m × 2.6 m) where they were kept up to 18 weeks of age. Group size varied between 40 and 60 birds. At 18 weeks of age all birds of the same hatch were transferred to one large pen (5.90 m × 10.20 m) to measure their locomotor activity (data not shown). At 26 weeks of age the hens were randomly assigned to five floor pens of 16 m^2. The pens were separated by a wire mash grid. Group size varied between 44 and 45 birds. All pens were equipped with hand filled round feeders (50 cm diameter), nipple drinkers (15–16 nipples), nests (1.20 m^2 nest space, lined with Astroturf mats), perches (23 cm/bird) and a litter area (1/3 of the total space). The litter area was covered with dry and friable wood-shavings (10 cm depth). A conventional layer mash containing 16.2% crude protein, 11.4 MJ ME/kg, 3.97% Ca, 0.60% P(total), 0.12% Mg, 0.16% Na, 0.21% Cl, 0.73% lysine, 0.37% methionine and 0.66 methionine + cystine, was provided ad libitum. The following trace elements and vitamins were supplemented through premix: 72 mg/kg Fe, 96 mg/kg Mn, 64 mg/kg Zn, 12 mg/kg Cu, 0.4 mg/kg Se, 1,28 mg/kg J, 12 000 IU. vit. A, 3000 IU vit. D, 41 mg/kg.vit. E, 3 mg/kg vit. B1, 6 mg/kg vit. B2, 6 mg/kg vit. B6, 0.03 mg/kg B12, 13 mg/kg pantothenic acid, 999 mg/kg folic acid, 0.1 mg/kg biotin, 0.5 mg choline chloride. Two third of the pen area was covered by a perforated plastic floor. The slats were raised at a height of 38 cm from the litter area. Artificial light (14 hrs) was provided through incandescent bulbs from 3 am to 5 pm. There was additional natural light through transparent plastic material at the upper part of the side wall of the pen. Depending on the fluctuation of the natural light, light intensity increased occasionally from 20 up to 2500 lux on sunny days. Climatic conditions were controlled by a thermostatically regulated ventilation system. At 29 weeks of age the birds were transferred an adjacent windowless poultry house with individual cages (0.45 m × 0.50 m). Light intensity was constantly 20 lux.

Lighting programmes during the rearing and laying period were organized according to management recommendations for White Layer Hybrids. The light programme started with 24 hours of light for 2 days. Day length was then reduced to 8 hours at 7 weeks of age and increased successively to 14 hours from 17 to 21 weeks of age.

Europ.Poult.Sci., 79. 2015, ISSN 1612-9199, © Verlag Eugen Ulmer, Stuttgart. DOI: 10.1399/eps.2015.84

Behavioural observations and tests

Feather pecking observations. At 26 weeks of age the birds were identified individually by numbered plastic tags on their back. The tags were made of flexible plastic material (6x16 cm) and fixed on the back of the hens by two strings which were slipped over both wings. A number for individual identification was written on the tag with black ink on a yellow adhesive tape. This method has been used to record feather pecking in the selection lines from generation 5 onwards. Behavioural observations started at 27 weeks of age. Depending of the different numbers of birds per hatch the number of pens varied from five to seven and group size from 36 to 42 birds. The number of observers was adjusted to the number of pens so that all pens were simultaneously observed in 20 min sessions. After each session the observers changed the pens in a rotational system so that all pens were observed by all observers at the same day. This procedure was repeated on three consecutive days. Access to litter area was closed during the time of observation. Birds delivering (FPD) and receiving (FPR) bouts of severe feather pecks, as described by KJAER et al. (2001), were individually recorded. During the observations the observers were positioned outside the pens. Observations started after a period of habituation, e.g. when the birds returned to feeding drinking and social behaviour. The observers received a special training to identify severe feather pecking and to differentiate this behavior from gentle feather pecking and aggressive pecking. Only bouts of severe feather pecking delivered and received are presented in this paper.

Feather eating test. The feather eating test started after the transfer of the hens to individual cages at 29 weeks of age. This test has been described by HARLANDER-MATAUSCHEK and BESSEI (2005). Briefly, ten feathers are offered on a transparent plastic sheet at the front of the cage every day. The feather holding sheet was placed in the middle of the cage so that it could not be reached by neighbouring hens. The number of feathers pulled out of the plastic lid and found on the cage floors, in the feeder and in the dropping pans were counted daily. The number of feathers eaten was calculated by the number of presented feathers minus the number of feathers left either on the plastic sheet, in the feeder or in the dropping pans.

Pencil test. A pencil with a length of 15 cm was moved towards the head of the individually housed birds. The reaction of the hens were scored from 1–5 (method of HUGHES and DUNCAN (1972) and modified as described by BESSEI (1980)).

The definition of the scores was as follows:

1- pecking at the pencil

2- no obvious response

3- moving to the left or right side

4- moving to the backside

5- attempts to escape

The hens were tested at 29 and 30 weeks of age. The mean scores of both measurements were used for statistical analyses.

Feather scores and body weight. At 26 and 39 weeks of age, plumage condition of individual hens was scored using the system reported by TAUSON et al. (2005). Six body areas (neck, breast, cloaca/vent, back, wings and tail) were scored separately using scores of 1–4 (1 = severe damage; 2 = moderate damage; 3 = slight damage and 4 = no damage). In addition the mean feather score of all body areas was calculated. Body weight was recorded after scoring at both ages.

Performance criteria. Hen day egg production (%), egg weight, daily feed consumption and feed conversion ratio (FCR) were recorded over a period of 17 days starting at 29 weeks of age.

Statistical analysis

In order to compare the results with earlier studies of the lines selected for high and low feather pecking (Bessei et al., 2013; Bennewitz et al., 2014) the birds were split in a low feather pecking (LFP; feather pecks delivered < 2) and high (HFP; feather pecks delivered >=2) feather pecking group. Data of the behavioural observations and tests did not follow the Gaussian distribution. Therefore the effect of line (HFP, LFP) was tested by Wilcoxon Test. Correlations between the criteria were calculated within lines using Spearman's rank correlation coefficient. All statistical procedures were carried out by JMP (SAS, 2007: JMP 7 Statistics and Graphics Guide, SAS Institute Inc., Cary, NC, USA).

Results

Feather pecks delivered and received, number of feathers eaten, feather scores and body weight at 26 and 39 weeks of age, pencil test scores and performance traits for the HFP and LFP subgroups are shown in Table 1. There were highly significant differences between HFP and LFP for feather pecks delivered (FPD) and the number of feathers eaten in the feather eating test. HFP showed significantly higher means than the LFP for FPD and feathers eaten but not for FPR. There were no significant differences between the two subgroups in body weight, hen-day egg production, egg weight, feed consumption and feed conversion ratio (FCR) and for the pencil test scores.

Table 1. Means, SD and P- values of F2- crosses divided in high (HFP, feather pecks delivered >=2) and low (LFP; feather pecks delivered < 2) feather pecking birds for pecks delivered (FPD) and received (FPR), number of feathers eaten, body weight at 26 and 39 weeks of age, pencil test scores (1 = pecking at the pencil; 5 = trying to escape) and performance traits. Means within the same column with different letters are significantly different (P < 0.05)

Mittelwerte, Standardabweichungen und P-Werte der F2- Kreuzungen unterteilt in Tiere mit einer hohen (HFP, >=2) und einer niedrigen (LFP, < 2) Federpickaktivität für ausgeteilte (FPD) und erhaltene (FPR) Pickschläge, Anzahl gefressener Federn, Körpergewicht im Alter von 26 und 39 Wochen, Bleistifttest Scores (1 = picken nach dem Bleistift; 5 = versuchen zu flüchten) und Leistungsmerkmale. Mittelwerte mit unterschiedlichen Buchstaben innerhalb derselben Spalte unterscheiden sich signifikant voneinander (P < 0.05)

Sub-Line	FPD	FPR	Feathers eaten	Pencil Test scores	Body weight 26 weeks	Body weight 39 weeks	Hen-day production (%)	Egg weight (g)	Feed consumption (g/day)	Feed conversion ratio
HFP	3.45^{a} ± 5.28	2.73 ± 1.91	6.54^{a} ± 33.50	3.20 ± 0.71	1465.36 ± 138.89	1560.21 ± 166.37	76.55 ± 30.44	52.39 ± 3.46	118.6 ± 20.63	1:3.38
LFP	0.73^{b} ± 3.22	2.55 ± 1.81	5.10^{b} ± 34.48	3.22 ± 0.78	1448.25 ± 157.02	1557.95 ± 173.22	72.14 ± 32.45	52.23 ± 3.78	117.2 ± 20.74	1:3.68
p	<.001	0.24	<.001	0.71	0.29	0.90	0.08	0.60	0.30	0.14

The means and SD of the feather scores of the different body parts at 26 and 39 weeks of age are shown in Table 2. There were significant differences between HFP and LFP in the feather scores for the wings and the tails at both ages but not for the other body areas. The mean feather score was significantly higher in HFP than in LFP at 39 weeks of age only.

Europ.Poult.Sci., 79. 2015, ISSN 1612-9199, © Verlag Eugen Ulmer, Stuttgart. DOI: 10.1399/eps.2015.84

Table 2. Feather scores of the different body parts and mean feather scores (1 = severe damage; 4 = no damage) over all body areas at 26 and 39 weeks of age of high (HFP, feather pecks delivered >=2) and low (LFP; feather pecks delivered < 2) feather pecking subgroups. Means within the same column with different letters are significantly different (P < 0.05)

Befiederungswerte der verschiedenen Körperregionen (1 = große Schäden; 4 = keine Schäden) und des Mittelwertes über alle Körperregionen im Alter von 26 und 39 Wochen der Tiere, die in hoch (HFP) und niedrig (LFP) pickende Gruppen unterteilt wurden. Mittelwerte mit unterschiedlichen Buchstaben innerhalb derselben Spalte unterscheiden sich signifikant voneinander (P < 0.05)

	Neck 26 wks	Neck 39 wks	Back 26 wks	Back 39 wks	Wings 26 wks	Wings 39 wks	Tail 26 wks	Tail 39 wks	Breast 26 wks	Breast 30 wks	Vent 26 wks	Vent 39 wks	Mean 26 wks	Mean 39 wks
HFP	3.59 ± 0.75	2.97 ± 0.92	3.69 ± 0.58	3.27 ± 0.74	3.81[a] ± 0.41	3.58[a] ± 0.54	3.03[a] ± 0.50	2.86[a] ± 0.58	3.29 ± 0.99	2.52 ± 0.98	3.24 ± 1.12	2.26 ± 1.23	3.44 ± 0.56	2.53[a] ± 0.51
LFP	3.55 ± 0.77	2.91 ± 0.88	3.64 ± 0.57	3.27 ± 0.71	3.72[b] ± 0.52	3.41[b] ± 0.59	2.87[b] ± 0.60	2.69[b] ± 0.62	3.33 ± 0.99	2.44 ± 1.01	3.22 ± 1.14	2.16 ± 1.20	3.39 ± 0.60	2.45[b] ± 0.50
p	0.27	0.40	0.08	0.86	0.03	<.001	<.001	<.001	0.50	0.29	0.87	0.34	0.14	0.03

Pair wise Spearman's Rank correlation coefficients for all criteria are shown in table 3. There was a positive ($p < 0.05$) correlation of FPD and FPR in LFP and a negative ($p < 0.05$) correlation in HFP birds. The correlation between FPD and the pencil test was negative ($p > 0.05$) and close to zero in HFP but positive ($p < 0.05$) in LFP.

Table 3. Spearman's rank correlation coefficients between feather pecks delivered (FPD) and received (FPR), pencil test scores, feathers eaten, feather score, and body weight at 26 and 39 weeks of age, and performance traits of F2- crosses divided in high (HFP, feather pecks delivered >=2; above the diagonal) and low (LFP; feather pecks delivered < 2; below the diagonal) feather pecking birds. Significant coefficients (P < 0.05) are marked in bold letters.

Spearman's Rangkorrelationskoeffizienten zwischen ausgeteilten (FDP) und erhaltenen (FPR) Pickschlägen, Bleistifttest, gefressenen Federn, Befiederungswerten und Körpergewicht im Alter von 26 und 39 Wochen und Leistungsmerkmalen bei F2- Kreuzungen, die in hohe (HFP; über der Diagonalen) und niedrige (LFP; unter der Diagonalen) Federpickaktivität unterteilt wurden. Signifikante Koeffizienten (P < 0.05) sind durch fett gedruckte Buchstaben markiert.

	FPD	FPR	Feathers eaten	Feather score 26 weeks	Feather score 39 weeks	Pencil test scores	Body weight 26 weeks	Body weight 39 weeks	Hen-day prod. (%)	Egg weight (g)	Feed cons. (g/day)	Feed conversion ratio
FPD	–	**-0.08**	**0.27**	0.02	0.04	−0.00	−0.00	−0.05	0.07	−0.00	0.04	−0.04
FPR	**0.21**	–	**-0.12**	**0.09**	0.04	0.06	**0.11**	0.06	−0.02	0.01	0.00	0.03
Feathers eaten	0.07	0.07	–	**-0.10**	**-0.11**	**-0.19**	0.10	0.07	**-0.12**	−0.02	**-0.11**	**0.12**
Feather score 26 weeks	0.05	0.11	**0.16**	–	**0.45**	**-0.14**	0.06	0.003	**-0.20**	**-0.17**	**-0.28**	0.06
Feather score 39 weeks	0.05	−0.01	0.08	**0.47**	–	**0.13**	−0.06	0.05	−0.03	−0.03	**-0.15**	**-0.09**
Pencil test scores	**0.18**	0.05	**-0.21**	**-0.20**	0.02	-	−0.01	0.08	**0.25**	**0.11**	**0.18**	**-0.22**
Body weight 26 weeks	**0.12**	**0.08**	**-0.10**	**0.06**	**0.04**	**-0.18**	–	**0.82**	**0.07**	**0.21**	**0.29**	0.06
Body weight 39 weeks	0.03	0.03	**-0.13**	−0.02	**0.09**	**-0.16**	**0.84**	–	**0.12**	**0.23**	**0.36**	0.03
Hen-day prod. (%)	**0.27**	0.09	−0.08	**-0.13**	−0.04	**0.27**	**0.14**	0.07	–	**0.22**	**0.64**	**-0.85**
Egg weight (g)	0.10	−0.09	−0.08	**-0.19**	−0.05	0.12	**0.16**	**0.21**	**0.16**	–	**0.29**	**-0.33**
Feed cons. (g/day)	**0.17**	0.11	−0.10	−0.12	−0.04	**0.14**	**0.36**	**0.34**	**0.64**	**0.15**	-	**-0.18**
Feed conversion ratio	**-0.25**	−0.01	0.07	**0.15**	−0.04	**-0.29**	0.12	**0.16**	**-0.84**	**-0.33**	**-0.16**	-

There was a positive ($p < 0.05$) correlation between FPD and feathers eaten in HFP. In LFP this correlation was also positive, but very low and not significant. The correlation coefficients between FPD and feather scores at 26 and 39 weeks of age were positive and close to zero in both, HFP and LFP. The correlations between FPD and body weight were low and not significant in either subgroup or age. The correlations of FPD with all performance traits were very low and not significant in HFP. In LFP there were positive ($p < 0.05$) correlations of FPD with hen-day egg production and feed consumption and negative ($p < 0.05$) correlations with feed conversion ratio.

Significant correlations of FPR were only found in HFP for feathers eaten, feather score at 26 weeks of age and body weight at 26 weeks of age. All other correlations of FPR and other criteria were not significant.

The correlations between the pencil test scores and feathers eaten were negative ($p < 0.05$) in HFP and LFP. There were also negative correlations of the pencil test and the feather score at 26 weeks of age in both, HFP and LFP. But at 39 weeks of age the correlation of the pencil test and the feather score was positive ($p < 0.05$) in the HFP birds. In LFP this correlation was also positive but not significant. The correlation between the pencil test score and body weight was significantly negative in LFP at 26 and 39 weeks of age. In HFP this correlation was close to zero at 26 weeks and ($p < 0.05$) positive at 39 weeks of age. In both lines the correlation coefficients of the pencil test scores and the laying performance traits were positive while pencil test scores and FCR showed a negative ($p < 0.05$) correleation. Feathers eaten were negatively correlated with the feather scores in HFP but positively correlated in LFP. There were negative ($p < 0.05$) correlations of feathers eaten and body weight at 26 and 39 weeks of age in LFP. In HFP these correlations were positive but not significant. The correlations of feathers eaten, egg number, egg weight and feed consumption were negative. The level of significance was only reached in the correlations of feathers eaten with hen-day production and feed consumption in HFP. Feathers eaten and FCR were positively correlated in HFP as well as in LFP, but the correlation was significant in the HFP only.

There was no significant correlation of feather score and body weight in either lines and age. The correlations among hen-day production, egg weight and feed consumption were positive ($p < 0.05$) in both lines. All performance criteria were negatively($P < 0.05$) correlated with FCR.

Discussion

Feather pecking, feather eating, feather score, body weight, and egg production criteria

Information on the relations between body weight and feather pecking or feather scores are scarce and contradictory. Taking feather scores as an indicator of feather pecking, Damme and Pirchner (1984) found a negative correlation between body weight and feather score with lighter birds showing more feather damage. Similar results were found by De Haas et al. (2013) in Dekalb White and ISA Brown parent stocks. However, Mills et al. (1988) did not find differences in the overall feather scores of broiler breeders and layers, although they differed widely in their body weight. In a study with the HFP and LFP selection lines of an earlier generation (Bessei et al., 2013), the HFP birds were significantly heavier than the LFP birds. In the present study, however, with higher numbers of hens there was no significant difference in body weight between the sub-lines. The correlations between body weight and feather scores were very low and significant in one case only (LFP at 39 weeks). These findings are in agreement with results of Emmans and Charles (1977), Tauson and Svensson (1980), Leonard et al. (1995) and Bilčík and Keeling (1999), who did not find differences in body weight between birds with good or poor feather conditions.

Body weight of commercial laying hens and parent stocks is usually controlled by applying special light and feeding programmes during rearing. These programmes, especially when feed restriction schedules are applied, may stimulate feather pecking. Consequently, low body weight coincides with poor feathering at a later age. The occurrence of similar feather scores in lines with large differences in body weight (Mills et al., 1988) or differing in feather score but not in body weight (as in the present study) show that there is no direct link between these criteria.

Birds receiving more feather pecks are expected to have poorer feather condition. In the present study, however, there was no difference in FPR between the subgroups, but LFP birds showed a significantly lower feather score, e.g. more damages, than HFP birds at the wings and tail and in the overall mean at 39 weeks of age. There was a tendency that HFP birds receiving more feather pecks (difference not significant) showed even better feather condition, and the correlations between FPR and feather score were positive in both subgroups. The lack of the expected relationship between feather pecks received and feather score in the present study may be explained by different factors: Not all feather pecks received may cause immediate feather damages or feather losses. In addition, the feather pecks are addressed to a large number of different birds of the flock. The percentages of birds which have been identified as target of feather pecks were 99.4% and 98.9% for the HFP and LFP respectively (Bögelein et al., 2014). Therefore the general level of damages was rather low at the time of scoring. Higher correlation coefficients between FPR and feather scores may appear after a longer period of exposure to feather pecking. But when HFP and LFP receive similar amounts of feather pecks (Table 1) we do not expect large differences between these subgroups.

Birds with poor plumage conditions have usually a high feed conversion ratio. This is due to higher heat loss, especially at low ambient temperatures (Emmans and Charles, 1977). It is generally known that under these conditions the birds compensate the loss of energy through increased feed consumption (Damme and Pirchner, 1984; Grashorn and Flock, 1987). In the present study, however, the overall feather score at 39 weeks of age was significantly lower in LFP than in HFP, but there was no significant difference between the HFP and LFP sub-lines in FCR. The difference in feather condition between the sub-lines was mainly based on the damages at the wings and the tail (Table 2). These regions have little influence on heat loss. This may explain the missing effect of the feather score on the means of the FCR (Table 1). As feed intake was similar in both sub-groups, FCR was mainly influenced by egg production.

The mean values show a higher egg production and better feed conversion rate of HFP as compared with LFP, though the differences are not significant. The assumption of better feed conversion in HFP is not reflected in the correlation coefficients, which are nearby zero (Table 3). Only in LFP the correlation between feather pecking and feed conversion rate was negative, showing the expected tendency. The results are also in contrast to studies in earlier generations of HFP and LFP selection lines, where HFP showed higher feed intake than LFP (Kalmendal and Bessei, 2012; SU et al., 2006). But similar to our results in the HFP subgroup, Yngvesson et al. (2004) found no difference in victims to cannibalism, cannibals and control hens for egg production, feed intake and feed conversion rate. There is obviously no consistent relationship between feather pecking, feed intake and feed conversion rate.

There were negative ($p < 0.05$) correlations of feather score at 26 weeks of age with percentage egg production and egg weight within both sub-lines indicating that birds with higher egg production showed poorer feather condition. This confirms results of Hughes (1980), Tullet et al. (1980), Mills et al. (1988) and Hagger et al. (1989).

The underlying mechanism of the relationship between egg production and feather conditions is not known. Hughes (1980) and Mills et al. (1988) assumed that feather abrasion through pre-laying activity of caged hens as cause of feather deterioration in high performing laying hens. This explanation cannot be considered in the present study since the birds were kept either in spacious pens or in large individual cages. It may be speculated that in high producing hens egg production has a higher physiological priority than maintenance of the feather cover. This may result in inadequate nutrient supply to the feathers, and consequently in lower resistance to abrasion and lack of replacement of cast feathers. The relative importance of heat loss and egg production of poor feathering in poultry cannot be appraised on the basis of our data and may be subject to further research.

Fear and feather score

It is assumed that fearful birds have poor plumage conditions (Hughes and Duncan, 1972; Choudary et al., 1972; Hughes and Black, 1974; Cuthbertson, 1978). There are different explanations for this relationship. Damaging feather pecking and pulling may lead to fear responses in the target hens. It has also been speculated that fearful birds may damage their plumage through flight activities. In the present study there was no difference in fear as measured by the pencil test between the HFP and LFP subgroups although they differed in feather scores at the wings and tails. In a previous study (Bögelein et al., 2014) using tonic immobility, open-field and emerge box test as fear criteria, LFP showed lower fear in open-field but higher fear in tonic immobility and emerge box test. There was obviously no consistent relationship between fear and feather pecking. The correlations between fear and feather scores confirm these findings. Although some of the correlation coefficients were significant, they showed both positive and negative directions. This in agreement with results of Albentosa et al. (2003) who did not find a consistent pattern of feather pecking and fear in different breeds. The alternative assumption that feather damages are caused by fear and flight can not been confirmed either. The birds in the present study were kept at low stocking density in floor pens during rearing and in large individual cages in the laying period and did not show high flightiness. It is not expected that feather cover is deteriorated under these conditions.

Feather pecking and feather eating

HFP- line birds have been reported to eat significantly more feathers than LFP-line birds (Harlander-Matauschek and Bessei, 2005; Harlander-Matauschek et al., 2006; Häusler, 2008). Birds within the HFP-line ate most feathers in the feather eating test and were also observed to eat most feathers from their pen mates (Bögelein et al., 2012). McKeegan and Savory (1999, 2001) also showed that hens which had been identified as feather peckers ate significantly more feathers than non-feather pecking birds. The number of feathers eaten in the present study was relatively high in both subgroups and the differences between HFP and LFP were not as large as reported for the selection lines of a previous generation (Bessei, 2011). The relatively high number of feathers eaten by the LFP may be due to the management conditions. In the present study all birds were raised on litter and were kept in a non-litter system for the feather eating test. Interruption of access to litter has been reported to stimulate feather eating (Bessei, 2011). This may also be the reason for the low phenotypic correlation between FPD and feathers eaten.

Conclusions

1) There are no consistent phenotypic relationships between feather pecking and body weight, egg production, fear or feather condition in the present study.
2) Plumage condition of HFP hens was better than in LFP hens, though the subgroups did not differ in feather pecks received. Therefore the difference may not be directly linked to feather pecking.
3) The assumption that poor feathering is related to fear could not be confirmed in the present study.
4) The correlations between feather scores and egg laying rate, egg weight and feed consumption were consistently negative, indicating higher performance correlates with poorer feather cover.
5) In high performing birds egg production may have a higher priority for nutrients than building of and maintaining the feather cover.
6) There was no consistent relationship between feather scores and feed conversion ratio on the individual basis.
7) HFP birds ate significantly more feathers than LFP birds, but the difference between the subgroups was not as large as reported in previous studies using the selection lines.

Acknowledgements

The authors acknowledge the financial support of the studies on feather pecking of the German Research Foundation (DFG) and the staff of the Institute of Animal Science, University of Hohenheim, for the assistance in behavioural observations.

Summary

It is generally assumed that there is a relationship between feather pecking, fear, feather condition and laying performance criteria in laying hens. This hypothesis was tested in a F2-cross of high (HFP) and low (LFP) feather pecking birds of White Leghorn origin. A total of 967 birds were first observed for the number of bouts of severe feather pecks delivered (FPD) and received (FPR) when kept in groups of random composition. The whole population was split for FPD in HFP and LFP using the threshold of ≥ 2 (HFP) and < 2 (LFP). The birds clearly differed in FPD but there was no significant difference for FPR between HFP and LFP. The subgroups were subjected to a pencil test at 29 weeks of age. At 26 weeks and 39 weeks of age body weight was measured and feather condition scored in different body parts (neck, breast, wings, vent and tail) using a scale from 0–4 (0 = worse, 4 = best). In addition the birds were tested for their feather eating behaviour and their laying performance criteria (hen-day egg production %, egg weight, feed consumption per day and FCR) at 29 weeks of age. In contrast to our expectation HFP birds showed a significant better plumage condition at 39 weeks of age than LFP birds. There were differences in feather scores at both ages for wings and tail. There were no differences between subgroups in the body weight at neither age. There were also no differences in the pencil test. But HFP birds showed a significant higher number of eaten feathers than LFP birds. This is in line with many other studies. But the difference was not as large as reported in previous studies. In contrast to our expectation there were no significant differences between the subgroups in performance, feed intake and FCR although LFP birds showed a significant poorer feather condition than HFP birds at 39 weeks of age. There were, however, negative correlations between feather score, performance, feed consumption and FCR within subgroups.Obviously there is no consistent relationships between feather pecking, fear, feather condition and performance criteria.

Key words

Laying hens, feather pecking, fear, performance criteria, selection

Zusammenfassung

Phänotypische Beziehungen zwischen Federpicken, Bepickt werden, Federfressen, Gefiederzustand, Furcht, Körpergewicht und Legeleistungsmerkmalen in einer F2- Kreuzung von Weißen Leghorn Linien, die auf hohes und niedriges Federpicken selektiert wurden

Es wird generell angenommen, dass eine Beziehung zwischen Federpicken, Angst, Gefiederzustand und Leistungskriterien bei Legehennen vorliegt. Diese Hypothese wurde in einer F2- Kreuzung aus Weißen Leghorn Linien mit hoher (HFP) und niedriger (LFP) Federpickaktivität untersucht. Es wurden hierfür 967 Tiere zuerst hinsichtlich ihrer Anzahl der ausgeteilten (FPD) und erhaltenen (FPR) Pickschläge beobachtet. Die gesamte Population wurde mit Hilfe einer Schwelle von ≥ 2 und < 2 Serien von starkem Federpicken in HFP- und LFP- Tiere unterteilt. Es gab deutliche Unterschiede in der Anzahl ausgeteilter Pickschläge. Aber es gab keine signifikanten Unterschiede in der Anzahl der erhaltenen Pickschläge zwischen HFP und LFP. Im Alter von 29 Wochen wurden die Tiere einem Bleistifttest unterzogen. Körpergewicht und Gefiederzustand von verschiedenen Körperteilen (Hals, Brust, Flügel, Bauch und Schwanz) wurden im Alter von 26 und 39 Wochen erfasst, in dem eine Skala von 0 bis 4 (0 = am schlechtesten, 4 = am besten) verwendet wurde. Zusätzlich wurden die Hühner noch hinsichtlich des Federfressverhaltens, der Furcht und der Leistungskriterien (Legeleistung, Eigewicht, Futterverbrauch und Futterverwertung) im Alter von 26 bis 39 Wochen untersucht. Entgegen unserer Erwartung zeigten HFP Tiere ein signifikant besseres Gefieder als LFP Tiere im Alter von 39 Wochen. Es zeigten sich allerdings nur Unterschiede in der Gefiederbeurteilung an Flügeln und Schwanz. Es gab keine Unterschiede zwischen den Linien im Körpergewicht. Ebenso gab es keine Unterschiede zwischen HFP und LFP im Furchttest. HFP zeigten aber eine signifikant höhere Anzahl gefressener Federn als die LFP. Dies bestätigt die Ergebnisse aus vorhergehenden Studien. Entgegen unserer Annahme gab es keine signifikanten Unterschiede zwischen den Untergruppen hinsichtlich ihrer Leistung, Futteraufnahme und Futterverwertung obwohl die LFP Tiere ein signifikant schlechteres Gefieder als die HFP aufwiesen. Innerhalb beider Linien wurden negative Korrelationen zwischen Gefiederzustand und Leistungskriterien sowie der Futteraufnahme gefunden. Die Korrelationen zwischen Gefiederzustand und Futterverwertung waren nicht konsistent. Auch für Federpicken, Furcht, Körpergewicht und Leistungsmerkmale konnte keine einheitliche Tendenz in den Korrelationen gefunden werden.

Stichworte

Legehennen, Federpicken, Furcht, Leistung, Selektion

References

ALBENTOSA, M.J., J.B. KJAER, C.J. NICOL, 2003: Strain differences in behavior, fear response and pecking tendency in laying hens. Brit. Poult. Sci. **44**, 333-344.

BENNEWITZ, J., S. BÖGELEIN, P. STRATZ, M. RODEHUTSCORD, H.P. PIEPHO, J.B. KJAER, W. BESSEI, 2014: Genetic parameters for feather pecking and aggressive behavior in a large F2-cross of laying hens using generalized linear mixed models. Poult. Sci. **93**, 810-817.

BESSEI, W., 1980: Untersuchungen über Furcht und Scheu bei Hühnern. In: Verhalten von Hühnern. Hohenheimer Arbeiten 108. Eugen Ulmer GmbH & Co, Stuttgart. ISBN 3-8001-8163-0, 9-22.

BESSEI, W., 2011: Le picage des plumes- Nouveaux aspects d'un vieux problème. 9ème Journées de la Recherche Avicole, Tours, Frankreich, 207-211.

BESSEI, W., H. BAUHAUS, S. BÖGELEIN, 2013: The effect of selection for high and low feather pecking on aggression - related behaviours of laying hens. Arch. Geflügelk. **77**, 10-14.

BIEDERMANN, G., N. SCHMIEMANN, K. LANGE, 1993: Investigation of the influence of the condition of the plumage of layers in different ages. Arch. Geflügelk. **48**, 280-285.

BILČÍK, B., L.J. KEELING, 1999: Changes in feather condition in relation to feather pecking and aggressive behaviour in laying hens. Br. Poult. Sci. **40**, 444-451.

BÖGELEIN, S., A. HARLANDER-MATAUSCHEK, W. BESSEI, 2010: Feather eating in laying hens from different genetic lines and its correlation between feather particles found in samples of feces: Proc. European Poultry Conference, Tours, France.

BÖGELEIN, S., T. HEIM, W. BESSEI, 2012: Feather eating and feather pecking: eating loose feathers does not prevent feather pecking. WPC 2012 Bahia, Brazil 5 - 9. August 2012 Book of Abstracts RE_PE_2011pc93_1.

BÖGELEIN, S., D. MARENCO HURTADO, J.B. KJAER, M.A. GRASHORN, J. BENNEWITZ, W. BESSEI, 2014: The phenotypic interrelationships between feather pecking, being feather pecked and fear criteria in White Leghorn lines selected for high and low severe feather pecking and their F2- crosses. Europ.Poult.Sci. **78**. 2014, ISSN 1612-9199, © Verlag Eugen Ulmer, Stuttgart. DOI: 10.1399/eps.2014.50.

BUITENHUIS, A.J., T.B. RODENBURG, M. SIWEK, S.J.B. CORNELISSEN, M.G.B. NIEUWLAND, R.P.M.A.Crooijmans, M.A.M.Groenen, P.Koene, H.Bovenhuis, J.J.Van Der Poel, 2005: Quantitative trait loci for behavioural traits in chickens. Livest. Prod. Sci. **93**, 95-103.

CHOUDARY, M.R., A.W. ADAMS, J.V. CRAIG, 1972: Effects of strain, age at flock assembly, and cage arrangement on behaviour and productivity in White Leghorn Type Chickens. Poult. Sci. **51**, 1943-1950.

CUTHBERTSON, G.J., 1978: An ethological investigation of feather pecking. Ph. D. Thesis, Univ. of Edinburgh.

DAMME, K., F. PIRCHNER, 1984: Genetic differences of feather- loss in layers and effects on production traits. Arch. Geflügelk. **48**, 215-222.

DE HAAS, E.N., 2014: The fearful feather pecker. Applying the principles to practice to prevent feather pecking in laying hens. Doctoral Thesis, Wageningen University.

DE HAAS, E.N., B. KEMP, J.E. BOLHUIS, T.G.G. GROOTHUIS, T.B. RODENBURG, 2013: Fear, stress, and feather pecking in commercial white and brown laying hen parent-stock flocks and their relationships with production parameters. Poult. Sci. 92, 2259-2269.

EMMANS, G.C., D.R. CHARLES, 1977: Climatic environment and poultry feeding in practice. In: Nutrition and the Climatic Environment. W. Haresing, H. Swan, and D. Lewis, ed. Butterworths, London, England, and Boston, MA.

GRASHORN, M., D. FLOCK, 1987: Genetisch-Statistische Untersuchungen des Befiederungszustandes an weißen (LSL) und braunen (LB) Legehybriden. Lohmann Informationen, Nov/Dez, 13-19.

HAGGER, C., C. MARGUERAT, D. STEIGER- STAFL, G. STRANZINGER, 1989: Plumage condition, feed consumption, and egg production relationships in laying hens. Poult. Sci. **68**, 221-225.

HÄUSLER, K., 2008: Untersuchungen zur Motivation zum Federfressen bei Legehennen. Dissertation, Universität Hohenheim.

HARLANDER-MATAUSCHEK, A., W. BESSEI, 2005: Feather eating and crop filling in laying hens. Arch. Geflügelk. **69**, 241-244.

HARLANDER-MATAUSCHEK, A., H.P. PIEPHO, W. BESSEI, 2006: The effect of feather eating on feed passage in laying hens. Poult. Sci. **85**, 21-25.

HOCKING, P.M., C.E. CHANNING, D. WADDINGTON, R.B. JONES, 2001: Age-related changes in fear, sociality and pecking behaviours in two strains of laying hens. Brit. Poult. Sci. **42**, 414-423.

HUGHES, B.O., 1980: Feather damage in hens caged individually. Br. Poult. Sci. **21**, 149-154.

HUGHES, B.O., I.J.H. DUNCAN, 1972: The influence of strain and environmental factors upon feather picking and cannibalism in fowls. Br. Poult. Sci. **13**, 525-547.

HUGHES, B.O., A.J. BLACK, 1974: The effect of environmental factors on activity, selected behaviour patterns and "fear" of fowls in cages and pens. Br. Poult. Sci. **15**, 375-380.

JONES, R.B., H.J. BLOKHUIS, G. BEUVING, 1995: Open-field and tonic immobility responses in domestic chicks of two genetic lines differing in their propensity to feather peck. Br. Poult. Sci. **36**, 525-530.

YNGVESSON, J., L.J. KEELING, R.C. NEWBERRY, 2004: Individual production differences do not explain cannibalistic behaviour in laying hesn. Br. Poult. Sci. **45**, 453-462.

KALMENDAL, R., W. BESSEI, 2012: The preference for high-fiber feed in laying hens divergently selected on feather pecking. Poult.Sci. **91,** 1785-1789.

KJAER, J.B., 2000: Diurnal rhythm of feather pecking behaviour and condition of integument in four strains of loose housed laying hens. Appl. Anim. Beh. Sci. **65**, 331-347.

KJAER, J.B., P. SØRENSEN, G. SU, 2001: Divergent selection on feather pecking behaviour in laying hens (*Gallus gallus domesticus*). Appl. Anim. Beh. Sci. **71**, 229-239.

LEONARD, M.L., A.G. HORN, R.W. FAIRFULL, 1995: Correlates and consequences of allopecking in White Leghorn chickens. Appl. Anim. Behav. Sci. **43**, 17-26.

MCKEEGAN, D.E.F., C.J. SAVORY, 1999: Feather eating in layer pullets and its possible role in the aetiology of feather pecking damage. Appl. Anim. Behav. Sci. **65**, 73-85.

MCKEEGAN, D.E.F., C.J. SAVORY, 2001: Feather eating in individually caged hens which differ in their propensity to feather peck. Appl. Anim. Behav. Sci. **73**, 131-140.

MILLS, A.D., J.M. FAURE, J.B. WILLIAMS, 1988: Feather loss and egg production in broiler breeders and layers. Ann. Zootech. **37**, 133-142.

PEGURI, A., C. COON, 1993: Effect of feather coverage and temperature on layer performance. Poult. Sci. **72**, 1318-1329.

RAMADAN, S.G.A., E. VON BORELL, 2008: Role of loose feathers on the development of feather pecking in laying hens. Br. Poult. Sci. **49**, 250-256.

SAS, 2007: JMP 7 Statistics and Graphics Guide, SAS Institute Inc., Cary, NC, USA.

SEFTON, A.E., D.C. CROBER, 1976: Social and physical environment influences on caged Single Comb White Leghorn layers. Canadian Journ. Animal Sci. **56**, 733-738.

SU, G., J.B. KJAER, P. SOERENSEN, 2006: Divergent selection on feather pecking behavior in laying hens has caused differences between lines in egg production, egg quality, and feed efficiency. Poult. Sci. **85**, 191-197.

TAUSON, R., S.A. SVENSSON, 1980: Influence of plumage condition on the hens feed requirement. Swed. J. Agric. Res. **10**, 35-39.

TAUSON, R., 1984: Plumage condition in SCWL laying hens kept in conventional cages of different designs. Acta Agriculturae Scandinavica **34**, 221-230.

TAUSON, R., J. KJAER, G.A. MARIA, R. CEPERO, K.-E. HOLM, 2005: Applied scoring of integument and health in laying hens. Animal Science Papers and Reports **23**, 153-159.

TULLET, S.G., M.G. MACLEOD, T.R. JEWITT, 1980: The effects of partial defaethering on energy metabolism in laying fowl. Br. Poult. Sci. **21**, 241-245.

VESTERGAARD, K.S., J.P. KRUIJT, J.A. HOGAN, 1993: Feather pecking and chronic fear in groups of red junglefowl: their relations to dustbathing, rearing environment and social status. Anim. Behav. **45**, 1127-1140.

Correspondence: Stefanie Bögelein, Institut für Tierhaltung und Tierzüchtung, FG Populationsgenomik bei landwirtschaftlichen Nutztieren (470c), Garbenstr. 17, Universität Hohenheim, Stuttgart 70599, Deutschland; E-Mail: s.boegelein@uni-hohenheim.de