

Individual plumage and integument scoring of laying hens on commercial farms: correlation with severe feather pecking and prognosis by visual scoring on flock level

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ABSTRACT Various plumage and integument scoring methods are commonly used to deduce the occurrence of severe feather pecking and cannibalism in laying hens. The aim of our study was to provide evidence of correlations between the occurrence of severe feather pecking and our individual plumage scoring system used under practical conditions on commercial farms with non-beak-trimmed and beak-trimmed layers (study I). In second step, we aimed to verify whether the results of the elaborate individual scoring may be predicted with a visual scoring method based on the total body scores of groups of birds (study II). For study I we observed the pecking behavior and performed an individual plumage scoring at the beginning, in the middle, and at the end of a laying period on 8 commercial farms. For study II we performed both an individual and a visual plumage scoring on 49 flocks on 45 farms at the beginning of the laying period and on 43 flocks on 41 farms at the end of the laying period. Spearman's Rho

revealed a correlation of the mean feather pecking rate with the total plumage score, the neck–back plumage score, and the total cannibalism score in all observation periods. A high feather pecking rate was correlated with severe plumage damage and the frequent occurrence of skin injuries. We conclude that both the total plumage score and the neck–back plumage score constitute a reliable indicator of the occurrence of severe feather pecking in the flocks assessed in this study. The results of study II suggest that the percental assessment of plumage damage on flock level in 3 categories (“visual score”) leads to a good prognosis of the actual, individually assessed plumage score. Therefore, the application (and documentation) of the visual score on a regular basis can provide a good evaluation of the development of the plumage condition of the flock. The visual score presented in this study is suggested as a suitable instrument for self-evaluation programs on farms.

Key words: plumage scoring, integument scoring, visual scoring, layer, feather pecking

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INTRODUCTION

Severe feather pecking (SFP) describes the vigorous pecking and pulling out of feathers or feather parts of conspecifics and leads to severe plumage damage (Bilcık and Keeling, 1999; Bestman et al., 2011). Damaged feathers are interesting pecking objects; they were found to receive significantly more SFP bouts than intact feathers and to facilitate the spread of feather pecking in

the flock (McAdie and Keeling, 2000). Furthermore, the severe pulling and plucking of feathers causes bald patches (McAdie and Keeling, 2002). Pecking on bald patches of skin may cause bleeding, which reinforces the pecking and leads to a quick spread of this abnormal behavior in the flock by imitation (Wechsler et al., 1998; Bilcık and Keeling, 1999; Kjaer and Vestergaard, 1999; Hartcher et al., 2015). Behavior observation and plumage damage scoring are common methods to assess the occurrence of SFP in layers. Few scientific studies used both methods and found matching results for the observation and scoring but did not calculate correlations (Johnsen et al., 1998; Huber-Eicher and Sebö, 2001). Bilcık and Keeling (1999) studied whether feather and

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aggressive pecking are related to plumage damage. Their results showed a significant positive correlation between SFP (but not gentle feather pecking) and plumage damage up to an age of 38 wk of life (Bilcik and Keeling, 1999). Correlations of SFP with plumage damage have so far mainly been calculated in experimental studies with a limited number of birds as compared with the flock size in commercial husbandry (Vestergaard et al., 1993; Hansen and Braastad, 1994; Bilcik and Keeling, 1999; Kjaer and Vestergaard, 1999; McAdie and Keeling, 2000). For layer chicks on a commercial rearing farm, the results of Zepp et al. (2018) showed a correlation between SFP pecks and plumage scoring in Lohmann Brown pullets. In that study 61.2% of pecks were directed against the back, 23.8% against the side of the body including the wing, and 10.4% against the neck. Another study with laying hens showed similar results: Wings, rump, tail, and back were the main targets for feather pecking (Ramadan and Borell, 2008).

To assess the welfare of laying hens, resource- and management-based indicators or animal-based indicators may be used (Knierim et al., 2016; Jung et al., 2020). A variety of plumage scoring systems has been used for scientific research in the past to deduce the occurrence of feather pecking or cannibalism or both (Tauson et al., 2005; Blokhuis et al., 2007; Campe et al., 2018; Jung and Knierim, 2019). There is a broad range of systems for individual scoring, modified according to the respective scientific question. The “henscore”—a method for the clinical evaluation of laying hens, which was evaluated in terms of repeatability (Gunnarsson, 2000)—and the scoring system developed by the “Lay-Wel” project (Tauson et al., 2005) are well-known examples. Another validated method is the “MTool” (Keppler et al., 2020). The total body score is usually calculated by summarizing scores of different body parts (Campe et al., 2018). For individual scoring, the animal needs to be caught and handled to assess the plumage condition and skin injuries on various body parts. Catching and handling are not only time consuming but also stressful for the birds (Cook et al., 2000; Bright et al., 2006). On the other hand, individual scoring is a detailed and valid method that has been used in many experimental and field studies (Abrahamsson et al., 1998; Bilcik and Keeling, 1999; Blokhuis et al., 2007; Keppler, 2008; Bright et al., 2016; Bestman et al., 2017; Campe et al., 2018). In addition, instead of just analyzing a total body score, various body-part-scores can be used to obtain more precise, multivariate models for identifying possible influencing factors (Campe et al., 2018).

Although a visual plumage assessment without catching individual animals is not only quicker for the assessor but also less stressful for the birds (Bright et al., 2006), this method may not be precise enough to gain information about the plumage and skin injury status of a flock. Therefore, if visual scoring is applied, it is usually based on visually scoring different body parts of 1 bird (Bright et al., 2006; Niebuhr et al., 2009; Giersberg et al., 2017). Bright et al. (2006) compared individual scoring with a visual scoring method for 5 body regions, and they found

correlations for both the body regions and the total body score. The authors suggested sampling 100 birds if there is little variation within flocks and 200 birds if there is large variation within the flock to accurately monitor changes in plumage condition (Bright et al., 2006). In another study, a total body score was only assessed by visual scoring and resulted in apparent differences between the hybrid lines studied, but the visual scoring system used was not validated (Damme, 1999). Visual scoring allows for assessing more flocks in less time and could be an efficient method for the self-monitoring of farms (Bright et al., 2006). Self-monitoring is useful as a warning system for the development of SFP or cannibalism (or both) in a flock (Blokhuis et al., 2007). An objective on-farm self-assessment benefits the farmer, as such an assessment enables early identification of certain animal welfare problems (Zapf et al., 2017). Self-assessment helps farmers to be more aware of the welfare of their hens and the effect of their management on it (Blokhuis et al., 2007). The implementation of a self-evaluation system for animal welfare indicators is for example mandatory according to German law and recommended on EU level (Blokhuis et al., 2007). The German Federal Law requires farmers to gather and assess animal-based indicators. The on-farm self-assessment shall ensure, that the animals are housed, fed and cared for according their physical and behavioral needs (Federal Ministry of Justice (2006). The aim of our study was to provide evidence of a correlation between the occurrence of SFP and our individual scoring system used under practical conditions on commercial farms with non-beak-trimmed and beak-trimmed layers (study I). In second step, we aimed to verify whether the elaborate individual scoring correlated with a visual scoring method based on the total body scores of a group of animals (study II).

MATERIALS AND METHODS

Study I: Correlation of Individual Plumage Scoring With SFP and With Skin Injuries

Farms and Animals The study took place on 8 commercial laying hen farms in Bavaria, Germany. Each farm had 1 flock of non-beak-trimmed laying hens (flocks 1–8), and farms 1 and 7 had an additional flock of beak-trimmed layers. During the laying period, the behavior of the animals was recorded in 3 observation periods (OP): OP 1 at the peak of the laying period between the 28th and 33rd wk of life, OP 2 in the middle of the laying period between the 42nd and 48th wk of life, and OP 3 at the end of the laying period between the 63rd and 68th wk of life (Table 1). Additional information on the flocks is published in Schwarzer et al. (2021).

The individual plumage scoring took place at the end of each video observation to ensure an undisturbed behavior observation during the fortnight before the scoring visit.

Table 1. Overview of flocks assessed in studies I and II. All animals were housed in aviaries, except flocks 8 and 38 in study II, which were housed in mobile hen houses.

Flock	Additional space	Hatch date DD.MM.YYYY	OP 1 week of life	OP 2 week of life	OP 3 week of life	Hybrid line(s)	Flock size nbt (bt)
Study I							
1.1	none	26.03.2012	29–31	44–46	64–66	DW + BB	3,589
1.2	none	26.03.2012	29–31	44–46	64–66	DW + BB	3,665 (bt)
2	none	06.10.2011	29–31	46–48	64–68	LB	4,250
3	FR + WG	27.01.2012	29–31	43–45	64–66	LB	4,212
4	FR + WG	04.05.2012	31–33	42–44	63–65	LB + DW	1,450
5	FR	20.02.2012	30–32	46–48	64–66	LB + LSL	2,004
6	FR + WG	31.12.2011	28–30	44–46	64–68	LB + LSL	2,000
7.1	none	31.12.2011	29–31	44–46	63–65	LB	4,500
7.2	none	31.12.2011	29–31	44–46	63–65	LB	5,000 (bt)
8	WG	14.01.2012	29–31	44–46	64–66	LB + LSL	1,481
Study II							
1	FR + WG	25.12.2014	26	n/a	67	LB + LSL	5,050
2	FR + WG	08.02.2015	20	n/a	67	LB	4,150
3	WG (O)	17.03.2015	20	n/a	66	LB Extra	3,600
4	none	27.03.2015	20	n/a	67	LB	5,500
5	FR + WG	15.04.2015	19	n/a	65	LB	4,750
6	none	15.04.2015	19	n/a	65	LB	5,400
7	FR + WG	27.03.2015	22	n/a	67	BB	5,143
8	FR (O)	06.05.2015	19	n/a	64	LB	225
9	WG (O)	19.05.2015	19	n/a	65	Lohmann Dual + LB	1,750
10	none	28.05.2015	19	n/a	66	LB	3,238
11	none	27.05.2015	20	n/a	66	LB	5,897
12	FR + WG	11.06.2015	19	n/a	66	LB	4,921
13	none	11.06.2015	19	n/a	66	LB	4,738
14.1	none	12.06.2015	19	n/a	n/a	LB	3,969
14.2	none	12.06.2015	19	n/a	n/a	LB	4,018
15	FR (O)	03.06.2015	21	n/a	67	LB	195
16	FR + WG (O)	24.06.2015	19	n/a	65	LB Plus	3,000
17	none	02.07.2015	19	n/a	66	LB + LSL	1,600
18	none	07.07.2015	20	n/a	65	LB	425
19	FR + WG (O)	16.07.2015	19	n/a	65	Lohmann Sandy	2,225
20	FR + WG	22.07.2015	20	n/a	65	LB	150
21	WG	22.07.2015	20	n/a	65	LB	150
22.1	FR	10.08.2015	19	n/a	66	LB	2,400
22.2	FR	10.08.2015	19	n/a	66	LSL	2,800
23	WG	03.09.2015	19	n/a	68	LB	990
24	FR + WG (O)	25.08.2015	20	n/a	84	LB	400
25	FR + WG	03.09.2015	19	n/a	69	LB + LSL	800
26	FR	02.09.2015	19	n/a	71	LB Extra	480
27	WG	01.09.2015	20	n/a	n/a	LB + LSL	1,500
28	WG	03.09.2015	21	n/a	n/a	LB + LSL	2,200
29	FR	13.09.2015	20	n/a	66	LB	700
30	WG	04.09.2015	21	n/a	66	BB + DW	3,198
31.1	none	24.08.2015	23	n/a	n/a	LB	4,850
31.2	none	24.08.2015	23	n/a	n/a	LB + LSL	4,850
32	WG	25.09.2015	20	n/a	58	LB	3,000
33	FR + WG	28.09.2015	20	n/a	66	LSL	500
34	none	01.09.2015	21	n/a	68	LB + LSL	470
35	FR + WG	25.09.2015	21	n/a	68	LB Extra	6,000
36	FR + WG (O)	25.11.2015	21	n/a	71	LB Extra	2,960
37	none	01.12.2015	20	n/a	70	LB	6,000
38	FR	09.12.2015	20	n/a	72	LB + LSL	1,500
39	WG	14.12.2015	19	n/a	65	LB + LSL	1,990
40	WG	17.12.2015	20	n/a	70	LB + LSL	2,500
41	WG	18.12.2015	20	n/a	66	LB	1,800
42	WG	17.12.2015	21	n/a	74	LB + LSL	2,117
43	WG	17.12.2015	21	n/a	70	LB + LSL	1,500
44	FR + WG (O)	29.12.2015	20	n/a	67	LB Plus	2,970
45.1	none	10.02.2016	18	n/a	64	BB	1,233
45.2	none	10.02.2016	18	n/a	64	DW	2,466

Abbreviations: BB, Bovans Brown; bt, beak-trimmed (2 flocks in study I only, all other flocks non-beak-trimmed); DW, Dekalb White; FR, free range; LB, Lohmann Brown; LSL, Lohmann Selected Leghorn; n/a, not applicable; O, organic farm; OP, observation period; WG, winter garden.

Video Observation For the video observation we used VTC-E220IRP SANTEC color cameras with IR-LEDs (Santronic AG, Wangen, Switzerland). Recording and video analysis were performed using the IP-video-surveillance and alarm-management software IndigoVision and the associated hardware (IndigoVision encoder

boxes and Ethernet Switch 8 Port, IndigoVision Group Ltd, Milton Bridge, Scotland, United Kingdom). We installed 6 to 8 cameras per flock in all available functional areas (perches, nest box area, litter area, and winter garden). This method allowed insight into sections of the functional areas of the barn. Two 24-h days per

camera and OP were analyzed. Overall, 476, seven hours of video recordings (mean: 15.9 h/flock/OP) were analyzed. SFP was defined as strong and powerful pecking at the plumage including pulling/plucking feathers or pecking at bald skin areas followed by an aversive reaction of the recipient. It was not always possible to distinguish between SFP and cannibalistic pecking on the videos, therefore, we could not perform separate analyses for SFP and cannibalistic pecking. For the video analysis we used methods as described in [Martin and Bateson \(2018\)](#). We performed a continuous recording for the first 5 min of each hour during the light phase and recorded SFP by using behavior sampling. We counted all individual severe feather pecking pecks as defined above observed in each observation period. As it was not possible to view all animals in the videos, we calculated the mean number of pecks per bird by dividing the total number of pecks observed in each observation period by the number of animals in the flock (severe feather pecking/bird, **SFP/B**). The results of the pecking behavior are published in [Schwarzer et al. \(2021\)](#).

Plumage and Integument Scoring In each OP, 30 hens were caught for individual plumage and integument scoring. In case a flock consisted of 2 strains (mixed flocks of brown and white layers), 15 hens of each strain were assessed. We used an individual scoring system based on the “henscore” ([Gunnarsson, 2000](#)) modified by [Niebuhr et al. \(2009\)](#) and [Tauson et al. \(2005\)](#), where plumage damages and integument lesions were scored separately for each of the body regions neck-dorsal, back, wings, neck-ventral, belly including cloaca, and legs ([Table 2](#)). Because the results of the behavior observation indicated that feather pecking was predominantly directed against the neck and back ([Plattner, 2015](#)), we calculated correlations of the mean number of

SFP/B with both the total plumage score (**TS**) and the body region scores for neck-dorsal and back (neck–back score, **NBS**).

The plumage score per body region was calculated by multiplying the points given for a specific body region (as explained in [Table 2](#)) by the number of hens assessed (e.g., 15 hens assessed had the back score 5, resulting in plumage score back = 75). For the TS we added up all body region scores. For the NBS we added up the scores for the 2 body regions neck and back. For skin lesions (= cannibalism score, **CS**) we used the same method: We first calculated the body region scores by adding up the scores of all hens assessed ([Table 2](#)) and then added up all body region scores for the total CS. Detailed results for plumage and integument scoring including management, husbandry, and microclimate factors are reported in [Lenz \(2015\)](#) and [Hammes \(2017\)](#).

Study II: Prognosis of Individual Plumage Score by Visual Plumage Scoring on Flock Level

Farms and Animals The study was conducted on 49 flocks on 45 farms with non–beak-trimmed laying hens. Plumage and integument assessment took place at the beginning of the laying period, 7 to 10 d after placement in the barn (OP 1: 18th to 26th wk of life). The second visit took place at the end of the laying period. The exact timing of the second assessment varied depending on length of the laying period (OP 2: 58th to 84th wk of life). The second assessment was conducted on 43 flocks on 41 farms. Of these flocks, 11 (25.6%) were mixed flocks consisting of 1 white and 1 brown hybrid line. The remaining 32 flocks were homogeneous ([Table 1](#)). Detailed results of the plumage and integument scoring are published in [Kaesberg et al. \(2018\)](#).

Plumage and Integument Scoring For the individual scoring, we used the same modified “henscore” ([Gunnarsson, 2000](#); [Blokhuis et al., 2007](#)) as in study I. In flocks with less than 200 birds, we assessed 20 birds, in flocks with more than 500 birds, we assessed 50 birds per flock individually. In case of mixed flocks, white and brown layers were caught according to their proportion in the flock. We scored the plumage in the body regions neck dorsal, back, and wings ([Table 2](#)). We added the body region “wings” to our already established NBS according to findings in the literature ([Ramadan and Borell, 2008](#); [Plattner, 2015](#)). Another reason was that it was not practical to omit the wings of the birds in the visual scoring (see below). The body region scores (neck dorsal, back, wing) were added up to obtain the TS per bird (minimum: 3; maximum: 15; [Table 2](#)).

In addition to the individual scoring, we conducted a visual scoring on herd basis for each flock in both OP. The visual scoring took place at 3 locations, evenly distributed throughout the barn (at the front, in the middle, and at the rear). At each location the visible plumage of 10 laying hens was assessed. Each of the 10 birds was given 1 combined score for the body regions

Table 2. Definitions for individual plumage and integument scoring (studies I and II) and visual scoring (study II), \emptyset = diameter.

Individual plumage scoring	Points
≤ 5 feathers damaged, no nude areas	5
> 5 feathers damaged, nude areas ≤ 1 cm \emptyset	4
Nude areas > 1 to ≤ 5 cm \emptyset	3
Nude areas > 5 cm \emptyset up to $\leq 75\%$ of the body region	2
Nude areas $> 75\%$ of the body region	1
Individual integument scoring	Points
No skin lesions	0
Skin lesion ≤ 0.5 cm \emptyset	1
Skin lesion > 0.5 cm to ≤ 2 cm \emptyset	2
Skin lesion > 2 cm \emptyset	3
Visual plumage scoring	Category
No or minor plumage damage: no or only few missing feathers	3
Severe plumage damage: many missing feathers, down feathers clearly visible	2
Nude areas > 5 cm \emptyset	1

For the individual plumage and integument scoring, separate body region scores per bird were given for: neck dorsal, back, wings, neck ventral, belly–cloaca, and legs.

For the visual scoring, 1 score was given per bird.

Table 3. Total plumage score (TS), neck–back plumage score (NBS), cannibalism score (CS), and mean number of severe feather pecking pecks per bird (SFP/B) assessed during 3 observation periods (OP).

F	Unit (strain)	OP 1				OP 2				OP 3			
		TS	NBS	CS	SFP/B	TS	NBS	CS	SFP/B	TS	NBS	CS	SFP/B
1	1 (DW)	236.0	108.5	17.5	0.09	98.5	46.5	30.5	0.13	117.0	66.5	29.0	0.12
	2 (BB)	260.5	123.0	18.0	0.21	130.5	74.0	33.0	0.17	89.5	50.5	15.0	0.16
	3 (DW, bt)	280.5	135.0	4.0	0.01	258.5	124.5	0.5	0.02	220.5	106.5	2.0	0.02
	4 (BB, bt)	274.0	131.0	3.0	0.03	262.0	125.5	0.0	0.02	222.5	110.0	2.0	0.00
2	5 (LB)	292.5	145.3	1.0	0.02	243.3	124.0	1.5	0.02	199.0	109.3	3.0	0.05
	3	6 (LB)	292.8	143.3	2.8	0.00	272.3	142.3	0.0	0.00	232.5	120.0	0.8
4	7 (LB)	242.0	113.0	8.5	0.18	169.0	86.5	16.0	0.11	151.0	77.0	14.5	0.09
	8 (DW)	248.0	124.5	8.0	0.05	194.5	103.0	10.5	0.07	166.0	86.5	13.5	0.04
5	9 (LB)	274.5	131.5	0.0	0.01	252.0	122.5	6.0	0.11	211.0	101.5	2.0	0.20
	10 (LSL)	260.0	120.0	3.0	0.05	224.5	93.5	6.0	0.04	194.5	99.0	5.0	0.06
6	11 (LB)	259.0	122.5	0.0	0.03	226.5	93.0	5.5	0.09	151.0	80.0	6.5	0.13
	12 (LSL)	284.0	130.0	2.0	0.04	249.5	112.5	9.0	0.03	166.0	88.0	7.5	0.08
7	13 (LB)	271.5	128.0	0.5	0.03	244.8	113.3	2.5	0.03	174.3	86.0	4.0	0.10
	14 (LB, bt)	282.0	142.0	5.0	0.01	254.5	128.0	32.5	0.02	216.8	113.3	17.5	0.05
8	15 (LB)	261.5	124.0	0.3	0.05	160.5	76.0	0.0	0.06	142.5	76.0	1.5	0.07
	16 (LSL)	253.5	112.0	12.5	0.05	203.0	91.0	8.5	0.06	148.5	74.5	11.5	0.08

Abbreviations: BB, Bovans Brown; bt, beak-trimmed (all other flocks non–beak-trimmed); DW, Dekalb White; F, flock number; LB, Lohmann Brown; LSL, Lohmann Selected Leghorn.

OP 1: 28th to 33rd wk of life, OP 2: 42nd to 48th wk of life, OP 3: 63rd to 68th wk of life.

neck dorsal, back, and wings, without catching the birds (Table 2). At each scoring location, we determined a percental proportion of the different scores (e.g., 10% birds with score 1 = nude areas larger than 5 cm, 40% birds with score 2 = severe plumage damage, and 50% birds with score 3 = intact plumage or minor plumage damage). The results of the 30 birds scored on the 3 different locations within the barn were used to calculate a mean value of the 3 categories per flock. The results of the visual scoring were used to calculate a prognosis of the individual score.

Statistics We used Spearman’s Rho statistic (r_s) for the quantification of the correlation between feather pecking rate and individual plumage score (study I). Ten flocks (8 non-beak-trimmed and 2 beak-trimmed) on 8 farms were included in the study. For the calculation of correlations, the 2 strains of mixed flocks (white and brown layers) were treated as different units, resulting in $n = 16$ units in total. We chose Spearman’s Rho, because the data were not normally distributed according to the Shapiro-Wilk-test.

For the prediction of the individual score by the visual score, we used a linear regression model (study II) with

individual plumage score as the outcome and visual score as the predictor. The prognostic error was determined by cross-validation and root-mean-square deviation. For the analysis the statistic programming language R (version 3.4.0) was used (R Core Team, 2017).

RESULTS

Study I: Correlation of Individual Plumage Scoring With SFP and With Skin Lesions

Table 3 lists the results for the TS, the NBS, the total CS, and the mean feather pecking rate per bird in the beak-trimmed and non–beak-trimmed flocks. We found a significant negative correlation between the mean feather pecking rate per bird and the TS in all OP (Table 4). A high feather pecking rate was correlated with a low plumage score. In other words, the plumage condition worsened with a rising feather pecking rate in the flock. There was also a negative correlation between the NBS and the mean feather pecking rate per bird. Finally, we found a positive correlation between the

Table 4. Correlations between the total plumage score, the neck–back plumage score, and the total cannibalism score with the feather pecking rate per recipient in all observation periods (OP).

	OP 1	OP 2	OP 3
Total plumage score	$r_s = -0.756^{**}$ CI = -0.924 to -0.487 $P = 0.001$	$r_s = -0.892^{**}$ CI = -0.928 to -0.505 $P < 0.001$	$r_s = -0.672^{**}$ CI = -0.87 to -0.242 $P = 0.004$
Neck–back plumage score	$r_s = -0.768^{**}$ CI = -0.944 to -0.595 $P = 0.001$	$r_s = -0.857^{**}$ CI = -0.947 to -0.611 $P < 0.001$	$r_s = -0.697^{**}$ CI = -0.881 to -0.284 $P = 0.003$
Total cannibalism score	$r_s = 0.769^{**}$ CI = 0.09 – 0.827 $P = 0.001$	$r_s = 0.832^{**}$ CI = 0.151 – 0.845 $P < 0.001$	$r_s = 0.519^*$ CI = -0.131 to 0.742 $P = 0.039$

OP 1: 28th to 33rd wk of life; OP 2: 42nd to 48th wk of life; OP 3: 63rd to 68th wk of life.

Statistical test: Spearman’s Rho (r_s); significance: * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

$n = 16$ units

Abbreviation: CI, confidence interval.

mean feather pecking rate per bird and the total CS (Table 4). A high feather pecking rate in the flock was correlated with the occurrence of many skin injuries.

Less than 1% (24 of 2,965) of the observed pecks in total was directed against the toes. We found hardly any injuries on the toes (mean toe CS of all OP: 1). Approximately 5% (138 of 2,965) pecks were directed against the belly–cloaca region and happened predominantly (103 pecks) in the litter area. Skin lesions in this body region were frequently detected during the laying period. The mean cloaca CS reached values up to 13.5 points (maximum: 45 points). The cloaca CS correlated negatively with the plumage score in all OP (OP 1: $r_s = -0.607$, $P = 0.013$; OP 2: $r_s = -0.791$, $P < 0.001$; OP 3: $r_s = -0.775$, $P < 0.001$; $n = 16$ units). The total CS correlated negatively with the TS in all OP (OP 1: $r_s = -0.580$, $P = 0.018$; OP 2: $r_s = -0.902$, $P < 0.001$; OP 3: $r_s = -0.945$, $P < 0.001$; $n = 16$ units). The results indicate a correlation of a high CS (= many skin injuries) with a low plumage score (= severe plumage damage).

Study II: Prognosis of Individual Plumage Score by Visual Plumage Scoring on Flock Level

At the beginning of the laying period (OP 1) data of 47 flocks were available, at the end of the laying period

(OP 2) the data of 42 flocks have been used. Plumage score for OP 1 ranged from 12.8 to 15 (Mean 14.4, SD 0.51) and for OP 2 from 7.1 to 13.5 (Mean 10.7, SD 1.5). We also calculated the prediction error (root-mean-square deviation) for both OPs. OP 1: 0.46 (SD = 0.1, Min = 0.1, Max = 0.88), OP 2: 0.9 (SD = 0.24, Min = 0.08, Max = 2.7). The visual plumage scoring resulted in the percental frequencies of the 3 plumage damage categories (Table 2) of each flock. The 3 categories were consolidated to obtain the “visual score” of the flock by adding up the proportional frequencies of the categories weighted with the values 1, 2, and 3.

$$\begin{aligned} \text{Visual score} &= 1 \times \text{category 1} + 2 \times \text{category 2} \\ &+ 3 \times \text{category 3} \end{aligned}$$

The maximum visual score is 3.0 (100% category 3 = intact plumage), the minimum value is 1.0 (100% category 1, nude areas). Values between these 2 extremes arise from different values of the categories. This calculation was conducted for both OP. The question of whether the individual score and the visual score are “the same” can be considered as a prognostic problem. Thus, we would like to know how well the individual score values can be predicted by the visual score values. The relationship can be described as linear (Figure 1); therefore, we used a linear regression model

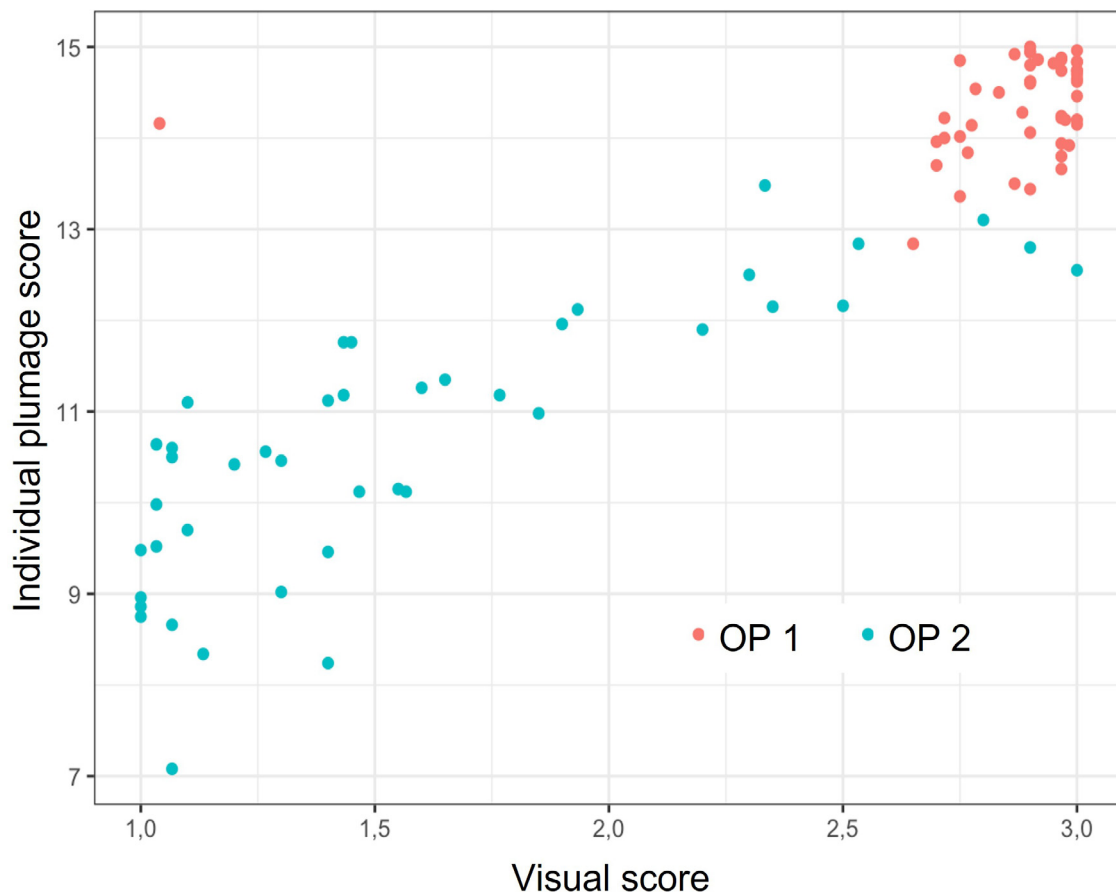


Figure 1. Relationship between the individual plumage score and the visual score during 2 observation periods (OP) in study II. OP 1 = red points ($n = 49$ flocks), 18th to 26th wk of life; OP 2 = blue points ($n = 43$ flocks), 58th to 84th wk of life.

for the following analysis. The prognostic error (root mean square error) was estimated using cross-validation: On average, the true individual plumage score was missed by 0.71 (SD = 0.15; minimum = 0.29; maximum = 1.33). The formula for the prognosis for the assessment at the beginning of the laying period (OP 1) was:

$$IPS_{OP1} = 7.704 + 2.296 \times VS_{OP1},$$

And the formula for the prognosis for the assessment at the end of the laying period (OP 2) was:

$$IPS_{OP2} = 7.451 + 2.044 \times VS_{OP2},$$

where *IPS* is the prognostic individual plumage score and *VS* the calculated visual score.

DISCUSSION

Correlation of Individual Plumage Scoring With SFP and With Skin Injuries

Many studies used plumage and integument scoring to deduce SFP activity in the flock (Craig and Lee, 1990; Staack et al., 2007; Giersberg et al., 2020; Schreiter et al., 2020). We tried to verify whether the pecking behavior correlates with plumage and integument scoring results under practical conditions on commercial farms with non-beak-trimmed layers. As described in Martin et al. (2005), SFP pecks were predominantly directed against the neck and back regions of the recipient. Accordingly, we frequently found nude areas in these body regions during individual scoring.

We calculated not only the correlation between the TS and the feather pecking rate but also tested whether the plumage scoring of neck and back would be sufficient to achieve a significant correlation. Scoring only few body parts would be less time-consuming and therefore be an interesting alternative if many flocks need to be assessed within a limited amount of time. Both the TS and the NBS correlated in all 3 OP significantly with the observed feather pecking rate. Bilcik and Keeling (1999) reported similar results with Hisex White hens. Body regions with damaged feathers or nude areas are attractive pecking targets (McAdie and Keeling, 2000). Therefore, we assume that nude areas evoke more SFP pecks and create a vicious circle. However, Liebers et al. (2019) could not find significant differences in the individual plumage assessment between different flocks of pullets, although significant differences were found in the behavior observations conducted simultaneously (Zepp et al., 2018). Liebers et al. (2019) concluded that their plumage scoring method was not detailed enough to detect little differences in the plumage condition of pullets, even though their scoring scheme was based on counting single damaged feathers in different body regions. Apparently for pullets, a much more detailed assessment is necessary than for laying hens.

The results of Allen and Perry (1975) indicate that cloacal cannibalism and SFP occur independently of

each other. However, numerous study have shown that the risk factors for the 2 behaviors are similar (Bestman et al., 2017; Jung et al. 2020), which might explain the correlations in our data: injuries in the belly–cloaca region correlated significantly with a low plumage score (= damaged plumage condition) in all 3 OP.

It was not possible to distinguish between SFP and cannibalistic pecking in the video analysis in our study because we could not determine whether the pecking led to skin lesions or not. Therefore, we used the SFP/R to calculate correlations with the total skin lesion score. McAdie and Keeling (2000) reported that laying hens prefer to peck at already damaged feathers, and several authors found cannibalistic wounds predominantly in body regions with damaged feathers (Allen and Perry, 1975; Huber-Eicher and Wechsler, 1997; Keppler, 2008). These findings support the hypothesis that feather pecking may develop into cannibalism, as already described by Savory (1995). We conclude that both the TS and the NBS constitute a reliable indicator of the occurrence of SFP in the flocks assessed in this study.

Prognosis of Individual Plumage Score by Visual Plumage Scoring on Flock Level

The percental assessment of plumage damage on flock basis in 3 categories (“visual score”) led to a good prognosis of the actual plumage score, which was based on individual plumage assessment. Our findings are in line with those of Bright et al. (2006), who also proposed the visual assessment of layers, but individually for different body regions of each bird. Giersberg et al. (2017) found a correlation between hands-on scoring and visual scoring for the plumage condition of most tested body regions (except belly and breast) and skin injuries.

Crucial for the success of our method is a systematic procedure, where at least 3 groups of 10 animals in different areas of the barn are assessed. Depending on the variability of plumage damage within the flocks, the assessment of more groups of animals might be useful, as suggested by Bright et al. (2006). The application of the visual score can be recommended to obtain an overview of the development of the plumage status in the flock during the laying period. It should be considered that scoring only 1 full body score may lead to an underestimation or, when used for scientific purposes, to missing influencing factors (Campe et al., 2018). The visual score complements the individual plumage scoring but is not suitable as an early warning system for cannibalism or diseases. To detect tiny cannibalistic wounds especially in the belly–cloaca region, a hands-on assessment of the birds is indispensable (Allen and Perry, 1975; Newberry, 2004).

Therefore, the application (and documentation) of the visual score on a regular basis can provide a good evaluation of the development of the plumage condition of the flock. German regulations require an on-farm self-assessment that shall ensure all farm animals are housed, fed, and cared for according their physical and behavioral

needs (Federal Ministry of Justice, 2006). We regard the “visual score” presented in this study as one suitable animal based indicator for self-evaluation programs on farms, in addition to animal welfare indicators proposed by other authors (Knierim et al. 2016; Zapf et al. 2017).

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Ethical statement: The work described in this article with research on life animals met the guidelines approved by institutional animal care and use committee (IACUC).

DISCLOSURES

There is no conflict of interest regarding any financial, personal, or other relationships with other people or organizations that could inappropriately influence or be perceived to influence this study.

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