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Feather pecking in domestic chicks: its relation to dustbathing and foraging

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Abstract. Feather pecking is a serious problem in poultry housing, as it may lead to feather damage, injuries and even mortality. We tested predictions of the two prevalent hypotheses claiming that feather pecking is related to dustbathing and foraging, respectively. Forty-two groups of 30 laying hen chicks, *Gallus gallus domesticus*, were reared in pens with a slatted floor. Access to sand as a dustbathing substrate and straw as a foraging substrate was varied between groups. The rate of feather pecking was measured in early development up to week 7. The provision of a sand area did not prevent the chicks from developing high rates of feather pecking that caused injuries. Chicks that had access to sand from day 10 showed higher rates of feather pecking than chicks that had access to sand from day 1. The provision of straw to chicks that had developed high rates of feather pecking led to a decrease in this behaviour. Chicks that could use both sand and straw from day 1 on did not show high rates of feather pecking, and no injuries were observed in these groups. There was no significant difference in dustbathing activity between housing conditions characterized by high or low rates of feather pecking. On the other hand, foraging activity was inversely related to the rate of feather pecking, and the occurrence of feather pecking could be delayed from week 4 to week 7 by postponing procedures that led to changes in foraging behaviour. In conclusion, the results show that the presence of an appropriate substrate for dustbathing does not prevent domestic chicks from developing feather pecking. On the other hand, housing conditions that promote foraging behaviour are effective in reducing and preventing feather pecking.

Feather pecking occurs both during rearing and in the laying period of domestic fowl, *Gallus gallus domesticus*. The behaviour causes serious economic and animal welfare problems, as it may result in feather damage, injuries and even the death of birds (Hughes & Duncan 1972; Allen & Perry 1975). Feather pecking is observed not only in caged birds but also in alternative housing systems (Appleby & Hughes 1991). The measure commonly used to control pecking damage is beak trimming. However, this measure is judged to have a negative impact on animal welfare, as it leads to significant behavioural changes that are probably caused by chronic pain (Duncan et al. 1989; Gentle et al. 1990; but see also Gentle et al. 1995).

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At present there are two main hypotheses for the causation of feather pecking discussed in the literature. The dustbathing hypothesis suggests that 'the primary cause of feather pecking is an abnormal development of the perceptual mechanism responsible for the detection of dust for dustbathing' (Vestergaard et al. 1993, page 1127). According to this hypothesis, feather pecking originates from dustbathing behaviour that is misdirected at the feathers of conspecifics if the birds do not have access to an appropriate dustbathing substrate in early development. In support of the hypothesis it has been found that chicks can be trained to dustbathe on feathers (Vestergaard & Hogan 1992; Vestergaard & Lisborg 1993), that the rate of feather pecking is increased during periods in which the birds are dustbathing or show intention movements of dustbathing (Vestergaard et al. 1993) and that pecks at feathers of conspecifics can be integrated into sequences of behaviour belonging to the

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dustbathing system (Vestergaard et al. 1990, 1993).

The ground-pecking hypothesis, on the other hand, suggests that 'feather pecking is to be considered as redirected ground pecking' (Blokhuis 1986, page 63). In a series of experiments a low rate of ground pecking was associated with a high rate of pecking at conspecifics and vice versa (Blokhuis & Arkes 1984; Blokhuis 1986, 1989). Blokhuis (1989) suggested that feather pecking may be related to foraging behaviour. He hypothesized that pecking at particles on the plumage of conspecifics may facilitate the direction of pecking on to feathers and that this redirection of ground pecking takes place because of the low incentive value of floors without litter. Other authors have also stressed the close resemblance of feather pecking to foraging behaviour (Hoffmeyer 1969; Wennrich 1975; Martin 1987; Baum 1995), and several studies have shown that feather pecking is reduced if the birds are provided with incentives that elicit foraging behaviour, such as litter (Hughes & Duncan 1972; Simonsen et al. 1980; Blokhuis & Arkes 1984; Baum 1995) or green food (Hoffmeyer 1969; Martin 1986).

In this paper we present results from experiments that were designed to test predictions of the dustbathing and ground-pecking hypotheses in domestic chicks. Naive chicks were chosen as subjects, as the occurrence of feather pecking in adult laying hens can be influenced by the housing conditions during rearing (Blokhuis & van der Haar 1989, 1992; Nørgaard-Nielsen et al. 1993). Groups of chicks were housed in pens with a slatted floor. Access to sand as a dustbathing substrate and straw as a foraging substrate was varied between groups, and dustbathing and foraging activities were measured to show the relation of these substrates to the two behaviour systems. Based on the dustbathing hypothesis we tested the predictions that (1) feather pecking should not develop if chicks have access to a sand area, and, more precisely, that (2) chicks deprived of sand during the first 10 days of life (possibly a sensitive period for the acquisition of a preference for sand as a dustbathing substrate; Vestergaard 1994) should develop more feather pecking than chicks that have access to sand from day 1 on. With respect to the ground-pecking hypothesis we tested the predictions that (3) the provision of straw is effective in decreasing the rate of feather pecking in chicks that show high rates of this behaviour, and that (4) chicks should not develop feather pecking if they are reared with access to straw.

GENERAL METHODS

Subjects and Housing

We used 1260 white layer chicks ('Lohman Selected Leghorn' hybrids) in three experiments. They were bought from a commercial breeder and introduced into the experimental housing conditions on the day after hatching. All individuals were females and not beak-trimmed. During the experiments they were housed in groups of 30 chicks at a density of 12.6 birds/m^2 which is close to the maximum density (14 chicks/m^2) permitted by the Swiss animal welfare legislation.

The experimental groups were kept in pens. There were 16 pens of identical size (265 × 90 cm, height 235 cm) built side by side along a corridor in a stable. Chicks in adjacent pens had no visual contact, as the pens were separated by plywood walls. These walls were 190 cm high and allowed auditory contact between all groups in the stable. Fresh air was introduced above the plywood walls. Spent air was removed from each pen by a separate pipe. Ventilation was controlled by temperature, and fresh air was heated in the cold season. The average daily temperature in the stable was 22°C. Each pen was illuminated by an incandescent light bulb (75 W). In addition, there was a fluorescent tube (36 W) per two pens. Light intensity at the height of the animals was about 60 lx. Day length was kept constant at 13 h (experiments 1 and 2: 0500–1800 hours) or 11 h (experiment 3: 0700–1800 hours) with a 15-min twilight phase at the start and end of the day.

In each pen a floor area of 200 × 90 cm next to the corridor (75.5% of the total floor) was made of slats (width 1 cm, 2.5 cm apart, 20 cm above the ground). The quality of the rest of the floor (65 × 90 cm) in the rear of the pens was varied in the experiments (see below). In the slatted floor area there were two cup drinkers and a suspended feeder (diameter 30 cm). The feed was covered by a wire grid which allowed unrestricted feeding while at the same time effectively preventing the chicks from scratching or dustbathing in the mash. The feeder was automatically refilled, and the animals had ad libitum access to a commercial starter food. On the narrow side of each pen there was a glass door (72 × 142 cm) opening on to the corridor from where behavioural observations were made.

Procedures

At arrival from the hatchery the chicks were randomly assigned to groups of 30 individuals and distributed among the pens. At this time an area of 150 × 90 cm of the slatted floor next to the corridor was covered with a perforated plastic mat (polyester tissue coated with PVC) to prevent the chicks from falling between the slats. The chicks were only allowed access to an area of 120 × 90 cm on this mat to ensure that they stayed close to the food and the water. The rest of the pen was partitioned by a wooden barrier (height 30 cm) that was removed when the chicks were 10 days old. During the first 17 days the chicks were provided with extra heat from a red heating lamp (250 W) suspended next to the feeder. This lamp was then replaced by a ceramic lamp (250 W) that provided heat but no light and was removed at the latest when the chicks were 6 weeks old.

During their third week of life we subjected the chicks to the following procedures: application of wing tags (2.5 × 2 cm) on each wing for individual recognition (day 15); change of the food structure from mash to pellets (day 15); and removal of the plastic mat on the slatted floor (day 17). The wing tags were fixed around the upper wings by means of a crêpe rubber tape (width 1.2 cm).

Ethical Note

All experiments were subjected to the authorization procedure prescribed by Swiss animal welfare legislation. We made the following efforts to minimize suffering in the chicks. (1) We minimized the number of groups used, the number of individuals in a group and the duration of the experiments. (2) We avoided unnecessary pain by frequently checking all pens for injured individuals. Regular checks were done twice a day (at 0700 hours and between 1600 and 1800 hours), and on most days there was a third check at midday. In addition the pens were checked during behavioural observations when the observer moved from one pen to the next and during the cleaning and rearranging of the treatments which had to be done roughly every second day. All injuries to the rump as well as serious injuries to other parts of the chick's body were covered with tar immediately upon detection. The tar treatment effectively prevented other chicks from pecking at the wounds. Pens with newly injured birds were checked more frequently. (3) Additional pens were available to separate seriously injured individuals from their group, and we had procedures to stop the induced feather pecking if necessary (reduction of light intensity and provision of long-cut straw).

Behavioural Observations

We observed the chicks of a given pen for periods of 15 or 30 min. During the observations we recorded all occurrences (Altmann 1974) of non-aggressive feather-pecking interactions between individuals. We found it impossible to count the exact number of feather pecks in a group of 30 chicks. We therefore recorded repeated pecks directed at the same individual as one interaction. An interaction ended when there were no more pecks during a period of 4 s. This should be kept in mind when rates of feather pecking are given in the text and in the figures. Only pecks at feathered parts of conspecifics were classified as feather pecking. Pecks at legs, beaks, combs or wattles were ignored.

In experiments 2 and 3 the all occurrences sampling was briefly interrupted every 5 min for a scan sample (Altmann 1974) of the activity of the chicks. For each scan we recorded the number of chicks engaged in nine mutually exclusive activities: dustbathing, foraging, feeding, drinking, preening, moving, standing, sitting, resting. In the results we present data for the first three activities which are of relevance for the dustbathing and ground-pecking hypotheses. They were defined as follows. (1) Dustbathing: the chick shows vertical wing-shaking (a typical behaviour of dustbathing, Kruijt 1964) or has shown vertical wing-shaking before the scan and not yet finished this dustbathing bout, that is, has not yet shown body/wing-shaking (Kruijt 1964) in a standing position or moved away from the dustbathing site. (2) Foraging: the chick pecks at the floor or at other parts of the pen or stands/moves with its head in a lower position than the rump. (3) Feeding: the chick stands next to the feeder with its head above the food. With dustbathing and foraging we differentiated whether the behaviour was performed on the slatted floor or on another substrate (sand, straw) provided in the rear of the pen.

The number, duration and time of the observation periods varied between experiments. Detailed information is provided in the methods of each experiment. All rates of feather pecking are given as number of pecking interactions/30 chicks/30 min. Data were recorded with the software system 'The Observer 3.0' (Noldus Information Technology, Wageningen, The Netherlands).

Statistical Analysis

The pens were treated as independent observational units. Given the small sample sizes in our experiments, it was not possible to assess reliably whether the data were normally distributed. We therefore used non-parametric statistics (Wilcoxon signed-ranks test, Mann–Whitney *U*-test). Statistical tests are two-tailed with an alpha level of 0.05. Bonferroni corrections were applied to multiple comparisons. All analyses were performed using Systat (Wilkinson 1992). Tables published in Rohlf & Sokal (1981) were used to assess statistical significance.

EXPERIMENT 1A

The dustbathing hypothesis predicts that feather pecking should not develop if the chicks are provided with an appropriate dustbathing substrate. In experiment 1A we tested this prediction by rearing groups of chicks in pens with or without a sand area. Sand is an adequate dustbathing substrate (van Liere 1991), and Sanotra et al. (1995) have shown that chicks prefer sand over feathers for dustbathing.

Methods

The experiment was carried out in 10 pens. In five pens the whole floor area consisted of slatted floor ('slats' condition). In the other five pens ('sand' condition) a plywood board measuring 65 × 90 cm placed in the rear of the pen was covered with a 5-cm layer of grey river sand (particles less than 2 mm in diameter). The chicks had access to this sand area from day 10 on, after the removal of the barrier (see General Methods).

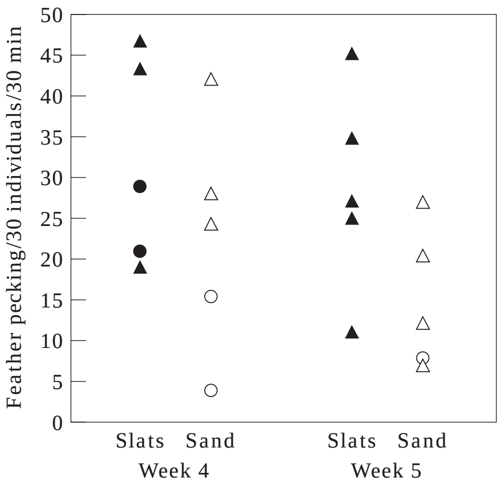

Figure 1. Rate of feather pecking in groups of chicks kept without (slats condition, ●, ▲) or with (sand condition, ○, △) access to a sand area. ▲, △: Groups with bloody injuries; ●, ○: groups without bloody injuries. Repeated pecks directed at the same individual were recorded as one feather-pecking interaction if the interruption between pecks was less than 4 s.

We recorded the behaviour of the chicks when they were 4 and 5 weeks old. In both weeks we observed each group of chicks for two periods of 30 min between 1000–1300 hours and 1300–1600 hours, respectively. We checked all pens at least once a day for the occurrence of bloody injuries.

Results

Contrary to the prediction, the provision of a sand area did not prevent the chicks from developing high rates of feather pecking. In both housing conditions there were bloody injuries caused by feather pecking. The rate of feather pecking did not differ significantly between the slats and the sand condition, either in week 4 or in week 5 (Mann–Whitney *U*-tests: week 4: median values 29.0 and 24.2; $U=18$, $N_1=N_2=5$, NS; week 5: median values 27.0 and 12.0, $U=20.5$, $N_1=N_2=5$, NS; Fig. 1).

We detected the first injuries in week 4. They were almost exclusively on the wings and the tail. The chicks could not usually tear out complete primaries or tail feathers but they broke them off leaving only the calamus in the skin. They then continued to peck at the calamus, injuring the skin and, more severely, the underlying muscle. Bloody injuries also stemmed from chicks pecking at growing tail feathers in which the vane was not yet unfolded. At this stage the shaft of a tail feather is still soft, and the blood vessels inside are easily hurt by vigorous feather pecks. We regularly observed that fresh blood was highly attractive to the chicks and resulted in more feather pecks directed at the bloody feathers.

In week 4 there were chicks with bloody injuries in six out of 10 pens (Fig. 1). The rate of feather pecking was, however, not statistically different in pens with or without injuries (Mann–Whitney *U*-test: median values 35.0 and 18.3; $U=20$, $N_1=6$, $N_2=4$, NS). By week 5 the number of pens with injured chicks had increased to nine. The conditions slats and sand did not differ significantly with respect to the age of the chicks at the first occurrence of a bloody injury (median values day 23 and 21.5; $U=12$, $N_1=5$, $N_2=4$, NS). We also compared the two experimental conditions by counting the number of days with fresh bloody injuries in each pen until the end of week 5. There was no statistical difference in this measure either (median values 3 and 2 days; $U=13.5$, $N_1=5$, $N_2=4$, NS).

EXPERIMENT 1B

If feather pecking is controlled by foraging motivation the provision of an attractive foraging substrate should result in a decrease in the rate of feather pecking. In experiment 1B we tested this hypothesis by giving chicks that had shown high rates of feather pecking over 3 weeks access to straw as a foraging substrate.

Methods

The experiment was carried out with the 10 groups of chicks of experiment 1A when they were 6 weeks old. The only change in the housing conditions was that an area of 65 × 90 cm in the rear of each pen was covered with long-cut straw. With the slats and the sand condition, respectively, the straw was offered on the slats or on the sand area. The chicks were observed when they were 45, 46 and 50–51 days old. On a given day we recorded their behaviour for three periods of 15 min between 1100 and 1600 hours. The start of the three observation periods was randomized for each pen but not changed from day to day. On day 45 the rate of feather pecking was measured in all groups before the provision of straw. On the evening of this day we added straw to the pens. On the next day the recording was repeated with all groups. We provided additional straw at the end of day 46 but not thereafter. We made a third recording with five groups each on days 50 and 51. Data from day 45 were compared both with data from day 46 and with the combined data from days 50 and 51. As a consequence, the alpha level was adjusted to 0.025.

Results

The provision of straw had a marked effect on the behaviour of the chicks. The rate of feather pecking significantly decreased from the day before to the day after the provision of straw (Wilcoxon signed-ranks test: median values 50.3 and 42.0; $T=0$, $N=10$, $P<0.01$). Five to six days after the first provision of straw the rate of feather pecking (median value 26.9) was still significantly lower than before the provision of straw ($T=0$, $N=9$, $P<0.01$).

EXPERIMENT 2A

Vestergaard (1994) hypothesized that chicks become imprinted on a dustbathing substrate during early development and that the sensitive period ends when the chicks are about 10–25 days old. Access to sand during the first 10 days of life may therefore be crucial in preventing the chicks from directing their dustbathing behaviour at the feathers of conspecifics and from developing feather pecking. In experiment 2A we tested this hypothesis by comparing the rate of feather pecking between groups of chicks that were reared with or without access to sand during the first 10 days of life. In addition, we measured the rate of feather pecking before and after the occurrence of bloody injuries, and we compared the percentage of chicks engaged in dustbathing and foraging behaviour between the two rearing conditions.

Methods

The experiment was carried out in 11 pens. In five pens the sand condition of experiment 1A was replicated. In these pens the chicks had access to a sand area (65 × 90 cm) in the rear of the pen from day 10 on, after removal of the barrier in the middle of the pen (see General Methods). Hereafter these pens are referred to as 'sand day 10' condition. The housing conditions in the other six pens differed in that the chicks had access to sand from day 1 on ('sand day 1' condition). In addition to the sand area (65 × 90 cm) in the rear of the pen these groups were offered sand in a plastic dish (diameter 40 cm, depth 6 cm) that was placed next to the heating lamp. The dishes were frequented by the chicks from day 1 on and removed on day 20. We measured the rate of feather pecking in weeks 3, 4 and 5. We differentiated whether a chick pecked at a feather or tore at a feather with a vigorous backward movement of the head. We observed each group of chicks twice per week for 30 min, once between 0800 and 1100 hours and once between 1300 and 1600 hours. The percentage of chicks engaged in dustbathing and foraging was calculated for each pen using the combined data of the scan samples of weeks 4 and 5. As data from the sand day 1 condition were also used for the statistical analysis of experiment 2B (see below), the alpha level was adjusted to 0.025.

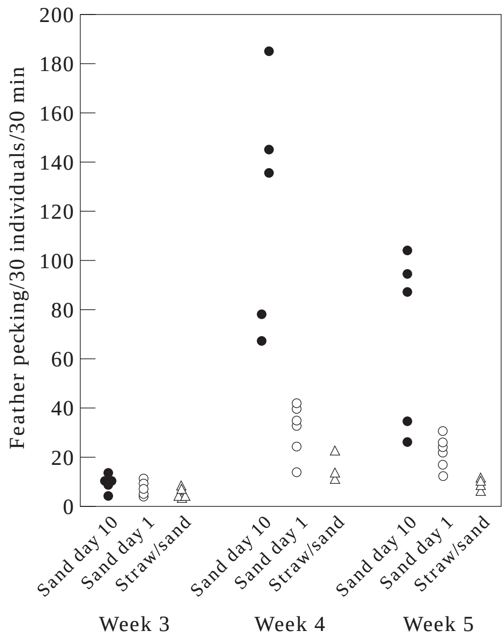

Figure 2. Rate of feather pecking in groups of chicks that had access to sand from day 10 on (sand day 10 condition, ●) or from day 1 on (sand day 1 condition, ○). △: Groups of chicks that had access to both straw and sand from day 1 on (straw/sand day 1 condition, experiment 2B). Repeated pecks directed at the same individual were recorded as one feather-pecking interaction if the interruption between pecks was less than 4 s.

Results

In week 3 there was no significant difference in the rate of feather pecking between the sand day 10 and the sand day 1 condition (Mann–Whitney *U*-test: median values 10.7 and 7.5; $U=21$, $N_1=5$, $N_2=6$, NS; Fig. 2). In weeks 4 and 5 the rate of feather pecking was generally increased, and chicks in the sand day 10 condition showed significantly more feather pecking than chicks in the sand day 1 condition (week 4: median values 135.5 and 34.0; $U=30$, $N_1=5$, $N_2=6$, $P<0.01$; week 5: median values 87.5 and 23.4; $U=29$, $N_1=5$, $N_2=6$, $P<0.01$; Fig. 2).

Access to sand from day 10 or day 1 on was not sufficient to prevent the occurrence of injuries caused by feather pecking. Bloody injuries were observed in four out of five pens in the sand day 10 condition and four out of six pens in the sand day 1 condition. To see if the injuries had an effect on feather pecking we computed for each pen the rate of feather pecking over the last 7 days before the first occurrence of a bloody injury and compared it with the rate of feather pecking in the first observation period 2–3 days after that event. There was no significant change in the rate of feather pecking (Wilcoxon signed-ranks test: median values before and after 30.2 and 35.0; $T=6$, $N=8$, NS). However, the intensity of the feather pecks changed markedly. After the first occurrence of a bloody injury in a pen the rate of tearing at feathers was significantly increased (median values before and after 4.1 and 6.6; $T=0$, $N=8$, $P<0.01$).

In weeks 4 and 5 dustbathing was almost exclusively performed in the sand area. All 57 dustbathing events recorded in the sand day 10 condition and 62 out of 64 dustbathing events recorded in the sand day 1 condition were performed in the sand area. The percentage of chicks engaged in dustbathing in the scan samples did not differ significantly between the two housing conditions (Mann–Whitney *U*-test: median values 1.5 and 1.4; $U=16.5$, $N_1=5$, $N_2=6$, NS). There was also no significant difference in the percentage of chicks that were foraging on the slatted floor (median values 5.8 and 6.3; $U=17$, $N_1=5$, $N_2=6$, NS). However, the percentage of chicks that were foraging in the sand area was significantly lower in the sand day 10 condition than in the sand day 1 condition (median values 12.0 and 16.0; $U=28$, $N_1=5$, $N_2=6$, $P<0.02$).

EXPERIMENT 2B

In this experiment we tested whether chicks can be prevented from developing feather pecking by providing them with an appropriate foraging substrate from day 1 on.

Methods

Experiment 2B was carried out in five pens simultaneously with experiment 2A. The housing conditions in these pens differed from the sand day 1 condition of experiment 2A in that, in addition to sand, long-cut straw was offered to the chicks from day 1 on. The straw was spread both on the sand in the dishes and on the sand area in the rear of the pens. Hereafter the five pens with straw are referred to as 'straw/sand day 1' condition. As with experiment 2A the five groups of chicks were observed twice per week for 30 min in weeks 3, 4 and 5 (once between 0800 and 1100 hours and once between 1300 and 1600 hours), and the percentage of chicks engaged in dustbathing and foraging was calculated for each group using the combined data of the scan samples of weeks 4 and 5. The alpha level was adjusted to 0.025 because data from the sand day 1 condition of experiment 2A were used for a comparison with data from experiment 2B.

Results

The chicks did not develop high rates of feather pecking in the straw/sand day 1 condition (Fig. 2). No bloody injuries were observed in these pens. In week 3 there was no significant difference in the rate of feather pecking between the straw/sand day 1 and the sand day 1 conditions (Mann–Whitney *U*-test: median values 4.0 and 7.5; $U=26$, $N_1=5$, $N_2=6$, NS; Fig. 2). In weeks 4 and 5, however, chicks in the straw/sand day 1 condition showed significantly less feather pecking than chicks in the sand day 1 condition (week 4: median values 12.0 and 34.0; $U=29$, $N_1=5$, $N_2=6$, $P<0.01$; week 5: median values 10.5 and 23.4; $U=30$, $N_1=5$, $N_2=6$, $P<0.01$; Fig. 2).

In weeks 4 and 5 dustbathing in the straw/sand day 1 condition was exclusively ($n=39$ events) shown in the rear of the pens where sand and straw were provided. There was no significant difference in the percentage of chicks engaged in dustbathing in the scan samples between the straw/sand day 1 condition and the sand day 1 condition (Mann–Whitney *U*-test: median values 1.0 and 1.4; $U=22.5$, $N_1=5$, $N_2=6$, NS). The percentage of chicks that were foraging on the slatted floor also did not differ significantly between the two housing conditions (median values 5.6 and 6.3; $U=17$, $N_1=5$, $N_2=6$, NS). However, the percentage of chicks that were foraging in the sand area was significantly higher in the straw/sand day 1 condition than in the sand day 1 condition (median values 24.3 and 16.0; $U=29$, $N_1=5$, $N_2=6$, $P<0.01$).

EXPERIMENT 3

In both experiments 1A and 2A high rates of feather pecking and bloody injuries caused by this behaviour were first observed in week 4. We therefore suspected that the procedures carried out in week 3 (application of wing tags, change of food structure, removal of the plastic mat covering the slats) could promote the development of feather pecking. Experiment 3 was designed to provide evidence for such an influence. We tested whether the application of wing tags has an effect on the rate of feather pecking and if the increase in feather pecking can be delayed by carrying out the procedures in week 6 instead of week 3.

Methods

The experiment was conducted in 16 pens. In all pens the housing conditions were identical to the sand day 1 condition in experiment 2A, that is, the chicks had access to a sand area of 65 × 90 cm in the rear of the pens from day 1 on. In five pens (condition 'tag') wing tags were applied as usual on day 15 whereas in another five pens (condition 'no tag') the chicks were only handled as they would have been when marked with wing tags. In both these conditions the structure of the food was changed from mash to pellets on day 15 and the plastic mat on the slats was removed on day 17. In six more pens ('delayed procedures' condition) the application of wing tags as well as the change of the food structure and the removal of the plastic mat were delayed until week 6 (days 36 and 38). All groups of chicks were observed in weeks 3, 4 and 5. In addition, the chicks of the delayed procedures condition were observed in week 6 (before the procedures) and week 7. We observed each pen twice for 30 min in each week once between 0800 and 1100 hours and once between 1300 and 1600 hours. Owing to technical problems data of one recording (week 5) of one pen of the delayed procedures condition were lost. The percentages of chicks engaged in dustbathing, foraging and feeding were calculated for each pen using the combined data of the scan samples of weeks 4 and 5. With the pens of the delayed procedures condition these percentages were also calculated separately for weeks 6 and 7.

Results

The application of wing tags had no significant influence on feather pecking. There was no difference in the rate of feather pecking between the tag and the no tag conditions before the procedure (Mann–Whitney *U*-test: week 3: median values 7.5 and 6.0; $U=22$, $N_1=N_2=5$, NS; Fig. 3) or after it (week 4: median values 23.0 and 17.9; $U=17$, $N_1=N_2=5$, NS; week 5: median values 49.4 and 27.0; $U=16$, $N_1=N_2=5$, NS; Fig. 3).

In week 3 chicks in the tag and the no tag conditions (data of both conditions combined) did not differ significantly from chicks in the delayed procedures condition with respect to feather pecking (Mann–Whitney *U*-test: median values 6.0 and 5.75; $U=34$, $N_1=10$, $N_2=6$, NS; Fig 3). However, in weeks 4 and 5 chicks in the tag and the no tag conditions showed significantly more feather pecking than chicks in the delayed procedures condition (week 4: median values 19.2 and 8.0, $U=60$, $N_1=10$, $N_2=6$, $P<0.002$; week 5: median values 37.0 and 11.0, $U=50$, $N_1=10$, $N_2=5$, $P<0.002$; Fig. 3).

In weeks 4 and 5 there were no significant differences between the percentages of chicks in the tag and the no tag condition that were recorded as dustbathing, foraging on the slatted floor, foraging in the sand area or feeding (Mann–Whitney *U*-test: dustbathing: median values 1.4 and 0.7; $U=20.5$, $N_1=N_2=5$, NS; foraging on slats: median values 8.5 and 10.4; $U=22$, $N_1=N_2=5$, NS; foraging in the sand area: median values 21.8 and 17.4; $U=15.5$, $N_1=N_2=5$, NS; feeding: median values 13.7 and 14.8; $U=13$, $N_1=N_2=5$, NS).

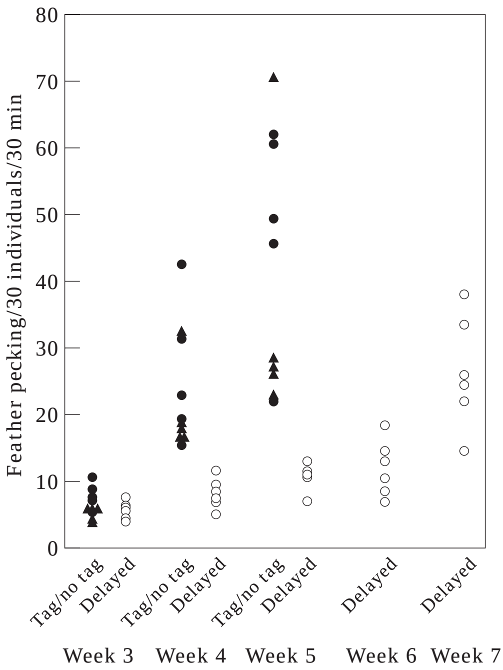

Figure 3. Rate of feather pecking in groups of chicks that were subjected to changes in the housing conditions either in week 3 (tag and no tag conditions, ●, and ▲, respectively) or in week 6 (delayed procedures condition, ○). Repeated pecks directed at the same individual were recorded as one feather-pecking interaction if the interruption between pecks was less than 4 s.

In the following we compare pens in which the housing conditions were changed in week 3 (tag and no tag conditions, data combined) with pens in which the housing conditions were changed in week 6 (delayed procedures condition). In weeks 4 and 5 there was no significant difference in the percentages of chicks engaged in dustbathing in the scan samples between the tag and no tag conditions and the delayed procedures condition (median values 0.8 and 1.1; $U=29.5$, $N_1=10$, $N_2=5$, NS). As with experiment 2 dustbathing was almost exclusively shown in the sand area. Seventy-six out of 77 recorded dustbathing events in the tag and no tag conditions and all 39 dustbathing events recorded in the delayed procedures condition were performed in the sand area. The percentage of chicks that were foraging on the slatted floor was significantly lower in the tag and no tag conditions than in the delayed procedures condition (median values 9.2 and 18.7; $U=50$, $N_1=10$, $N_2=5$, $P<0.002$). On the other hand, the percentage of chicks that were foraging in the sand area was significantly higher in the former condition than in the latter (median values 17.4 and 5.9; $U=48$, $N_1=10$, $N_2=5$, $P<0.01$). A significantly lower percentage of chicks was recorded as feeding in the tag and no tag conditions than in the delayed procedures condition (median values 14.3 and 28.3; $U=50$, $N_1=10$, $N_2=5$, $P<0.002$).

By week 6 the rate of feather pecking in the delayed procedures condition was still at a low median value of 11.75. After the procedures, however, this rate was significantly increased with a median value of 25.25 in week 7 (Wilcoxon signed-ranks test: $T=0$, $N=6$, $P<0.05$; Fig. 3). There was no significant difference in the percentage of chicks engaged in dustbathing in the scan samples before and after the procedures (Wilcoxon signed-ranks test: median values before and after 2.1 and 1.1; $T=5$, $N=6$, NS). Dustbathing was performed exclusively in the sand area (43 and 29 events recorded before and after the procedures, respectively). There was no significant difference in the percentage of chicks that were foraging in the sand area before and after the procedures (median values before and after 8.1 and 7.9; $T=5$, $N=6$, NS). However, there was a significant decrease in the percentage of chicks that were foraging on the slatted floor (median values before and after 17.8 and 9.9; $T=0$, $N=6$, $P<0.05$) and in the percentage of chicks that were feeding (median values before and after 21.4 and 12.8; $T=0$, $N=6$, $P<0.05$).

DISCUSSION

Our results are not in accordance with the model presented by Vestergaard & Lisborg (1993) which hypothesizes that 'the association between feathers and dustbathing develops as a result of early pecking and scratching at feathers under circumstances where access to sand is absent' (page 294). In experiment 2A chicks that had access to sand from day 1 on nevertheless developed feather pecking that caused injuries. Chicks with access to both sand and straw, on the other hand, had only very low rates of feather pecking and no injuries were observed in these groups (experiment 2B). As the size of the sand area and the quality of the sand did not differ between the two housing conditions, access to sand for dustbathing cannot be the crucial factor for the development of high rates of feather pecking. Similarly, in experiment 3 chicks of varied age showed significant increases in feather pecking following experimental procedures (application of wing tags, removal of the plastic mat covering the slatted floor, change from mashed to pelleted food), although they invariably had access to a sand area. The significance of dustbathing behaviour for the development of feather pecking is also questioned by the fact that we found no difference in dustbathing activity between housing conditions characterized by high or low rates of feather pecking in experiments 2 and 3.

Vestergaard & Hogan (1992) and Vestergaard & Lisborg (1993) have shown that chicks can be trained to dustbathe on a skin with feathers. However, it also became clear in these studies that feathers are not very attractive as a substrate for dustbathing. Red junglefowl chicks, *Gallus gallus spadiceus*, that were trained on feathers performed less dustbathing during training than conspecifics that were trained on black or white sand, and only four out of 16 chicks became entrained on feathers compared with 14 out of 16 and nine out of 16 chicks that were trained on black and white sand, respectively (Vestergaard & Hogan 1992). In domestic chicks, the frequency of vertical wing-shaking performed during training tests did not differ between feather-trained and sand-trained individuals, but the experience of sand after this training loosened the association between feathers and dustbathing. Over three consecutive choice tests, feather-trained chicks performed an increasing proportion of all vertical wing-shakes on sand (Vestergaard & Lisborg 1993). In addition, Sanotra et al. (1995) found that naive chicks prefer sand over feathers for dustbathing.

Based on these results, it is plausible to predict that chicks should not develop feather pecking when sand is provided as a substrate for dustbathing during early development. In the present study, however, chicks showed high rates of feather pecking when they were 4 and 5 weeks old although they had been reared with access to sand from day 1 onwards. Also in contrast to this prediction, Nørgaard-Nielsen et al. (1993)

reported low plumage scores (indicating serious problems with feather pecking) in laying hens that had been reared on a substrate consisting of dark sand with dry peat on the top and transferred to a laying house in which they had access to a sand area. In conclusion, access to an appropriate dustbathing substrate does not reliably prevent the development of feather pecking.

In experiment 2A chicks that had access to sand from day 1 on developed significantly less feather pecking than chicks that had access to sand only from day 10 on. This result seems to be in accordance with the assumption of Vestergaard (1994) that chicks become imprinted on a dustbathing substrate during early development. In our experiment, however, chicks that had no access to sand during the first 10 days after hatching dustbathed as exclusively on sand as chicks that could use sand from day 1 on. As discussed above, the assumption of Vestergaard (1994) is questionable, because chicks that are trained to dustbathe on feathers switch to sand as a dustbathing substrate after experience with sand (Vestergaard & Lisborg 1993; Sanotra et al. 1995). Furthermore, Petherick et al. (1995) found that chicks reared on peat or wire both started dustbathing when peat was placed below their cage so that they could see it but not interact with it. They suggested that domestic chicks hatch with a predisposition which enables them to recognize a substrate suitable for dustbathing.

The difference in the rate of feather pecking between chicks that had access to sand from day 1 or day 10 on can also be explained by the hypothesis that feather pecking is related to foraging behaviour. Sand is not only an appropriate substrate for dustbathing; it can also elicit pecking that is related to foraging behaviour. We found that foraging activity in the sand area was significantly increased in chicks that had access to sand from day 1 compared with chicks that were deprived of sand until day 10. With regard to the ground-pecking hypothesis our results therefore suggest that the incentive value of sand as a foraging substrate is enhanced if the chicks already have access to sand during the first days of life. To prevent the misdirection of foraging pecks at feathers of conspecifics it may thus be crucial to provide chicks with an attractive foraging substrate in early development. When chicks had access to both straw and sand from day 1 in experiment 2B they showed significantly more foraging activity (on these substrates) and significantly less feather pecking in weeks 4 and 5 than chicks that had access to sand but not straw from day 1.

In experiment 3 the occurrence of high rates of feather pecking was delayed from week 4 to week 7 when the experimental procedures were postponed from week 3 to week 6. This result is in accordance with the hypothesis that feather pecking is related to foraging behaviour, as the removal of the plastic mat covering the slatted floor and the change from mashed to pelleted food were associated with changes in foraging and feeding activities. There was a significant decrease in foraging activity on the slatted floor after removal of the plastic mat and, in accordance with Jensen et al. (1962) and Savory (1974), we found that the chicks spent less time at the feed trough when fed on pellets instead of mash. The two procedures coincided with a significant increase in feather pecking. However, as we did not independently vary the change from mash to pellets and the removal of the plastic mat in our experiments, we are not able to separate the influence each of the procedures had on the development of feather pecking.

The results of the scan samples in experiment 3 suggest that the development of feather pecking depends not only on the absolute level of foraging activity but also on qualitative aspects of this behaviour. Chicks in the tag and no tag conditions did not differ in overall foraging activity from chicks in the delayed procedures condition in weeks 4 and 5. However, chicks in the former groups showed significantly more foraging activity in the sand area whereas chicks in the latter groups performed significantly more foraging on the slats which were (in these groups) covered with a plastic mat. As high rates of feather pecking were observed only in the former groups, the quality of foraging behaviour elicited by a given substrate may have a major influence on the occurrence of feather pecking.

In accordance with Martin (1986) and Hughes & Duncan (1972), we observed an increase in the rate of feather pecking and feather damage, respectively, when the chicks were 4 weeks old (experiments 1A, 2A). Also at this age, we recorded the first injuries caused by feather pecking. Based on our qualitative observations we suggest that feather pecking frequently progresses to cannibalism at this age because pecks at growing feathers are likely to result in bloody injuries that are attractive for pecking. In addition, we found a significant increase in the rate of tearing at feathers after the occurrence of bloody injuries. However, our results indicate that feather pecking is a prerequisite and not a consequence of this type of cannibalism, as there was no difference in the rate of pecking at feathers (including tearing) before and after the first occurrence of a bloody injury in a group. In experiment 2B the chicks did not develop high rates of feather pecking, and no injuries were observed in these groups.

To conclude, the results of our experiments cannot be explained by the hypothesis that feather pecking develops when the birds do not have access to an appropriate substrate for dustbathing. On the other hand, our results are in accordance with the hypothesis that feather pecking is to be considered as redirected foraging behaviour. Changes in the housing conditions with respect to incentives that elicit foraging behaviour were associated with predicted changes in the rate of feather pecking. When the chicks had access to an appropriate foraging substrate from day 1 on, feather pecking did not develop. The practical implication of this study is that chicks should be reared in housing systems that promote foraging behaviour. There were also indications that experiences with a foraging substrate in early development may have an effect on the efficiency of this substrate in reducing feather pecking during rearing. As a consequence, chicks should be allowed access to an appropriate foraging substrate during the first days of life. Further experiments are necessary to identify key features of the foraging substrate that are appropriate to prevent the development of feather pecking.

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