British Poultry Science (2000) **41:** 16–21

Effect of foraging material and food form on feather pecking in laying hens

V. AERNI, H. EL-LETHEY AND B. WECHSLER[1]

Universität Bern, Zoologisches Institut, Abteilung Sozial- und Nutztierethologie, Ethologische Station Hasli, Hinterkappelen and [1]Bundesamt für Veterinärwesen, Tänikon, Switzerland

Abstract 1. The aim was to test whether provision of foraging material and food form influence feather pecking and feather damage in laying hens.
2. From week 19 of age, 16 groups of 11 hens (white Lohman Selected Leghorn hybrids) were kept in pens with or without access to long-cut straw as foraging material and fed on either mash or pellets.
3. Foraging behaviour was increased in hens with access to straw and time spent feeding was increased in hens fed on mash. In addition, hens fed on mash had longer feeding bouts and higher rates of pecking at the food during feeding than hens fed on pellets.
4. There were interaction effects of foraging material and food form on both feather pecking and feather damage. High rates of feather pecking and pronounced feather damage were only found in hens housed without access to straw and fed on pellets. In groups characterised by high rates of feather pecking the hens also showed more severe forms of this behaviour.
5. Differences in the time budgets of hens kept in different housing conditions suggested that birds fed on mash used the food not only for feeding but also as a substrate for foraging behaviour.
6. In order to avoid problems with feather pecking it is recommended that laying hens are provided with foraging material and fed on mash.

INTRODUCTION

Feather pecking in laying hens is a serious animal welfare problem. The behaviour not only leads to feather damage but may also result in injuries and even the death of birds (Hughes and Duncan, 1972; Allen and Perry, 1975, Appleby and Hughes, 1991). It is therefore of great importance to understand the causation of feather pecking and to identify housing conditions in which this abnormal behaviour does not develop.

Several studies have shown that feather pecking in laying hens is reduced if the birds are provided with incentives that elicit foraging behaviour, such as litter (Hughes and Duncan, 1972; Simonsen *et al.*, 1980; Blokhuis and Arkes, 1984; Blokhuis, 1986), longcut straw from perforated plastic baskets (Nørgaard-Nielsen *et al.*, 1993) or polystyrene blocks (Huber-Eicher and Wechsler, 1998; Wechsler and Huber-Eicher, 1998). In a series of experiments we found an inverse relationship between the time the birds spend on exploratory and manipulative foraging behaviour away from the feeder and the rate of feather pecking (Huber-Eicher and Wechsler, 1997, 1998; Hoffmeyer, 1969; Wennrich, 1975; Blokhuis, 1986). We therefore concluded that feather pecking should be regarded as redirected foraging behaviour (Huber-Eicher and Wechsler, 1998).

Feather pecking in laying hens is possibly also related to the food form. Appleby and Hughes (1991) suggested that hens fed on pellets may be more likely to develop feather pecking than hens fed on mash, as time spent on feeding is reduced with pelleted food (Jensen *et al.*, 1962; Savory, 1974; Savory and Mann, 1997). In line with this hypothesis, Bearse *et al.*, (1949) and Walser (1997) reported a greater tendency for feather pecking with pelleted food in growing pullets and adult laying hens, respectively. In a recent study with growing pullets, however, Savory and Mann (1997) found no significant effect of food form on feather pecking.

The present study investigated both the separate effects and the interaction effect of foraging material and food form on feather pecking using a 2×2 factorial design. From week 19 of age, groups of hens were kept in pens with or without long-cut straw as foraging material and fed on mash or pellets. It was expected that feather pecking and feather damage would be more pronounced if the hens did not have access to foraging material and if food was provided in pelleted form. Moreover, we were interested in differences in the time budgets of hens kept in different housing conditions, especially with respect to foraging behaviour and feeding.

METHODS

Animals and housing conditions

The experiment was carried out with a total of 176 white laying hens (Lohman Selected Leghorns

Correspondence to: B. Wechsler, Bundesamt für Veterinär wesen, Zentrum Für tiergerechte Haltung: Wiederkäuer und Schweine FAT, 8356 Tänikon, Switzerland. E-mail: Beat.Wechsler@fat.admin.ch
Accepted for publication 28th June 1999.

ISSN 0007–1668(print)/ISSN 1446–1799(online)/00/010016–06

hybrids) assigned at random to groups of 11 individuals and distributed among 16 pens of identical size (265 × 90 cm, height 235 cm; 4·6 hens/m^2) in week 18 after hatching. The birds were not beak-trimmed and had been reared by a commercial breeder in an aviary system, as part of a flock of 6400 birds at a density of 12·3 birds/m^2. Day length was 10 h (natural daylight), the floor was covered with sawdust and there were several perches at different heights. On arrival from the farm the plumage condition of each hen was perfect.

The 16 experimental pens were side by side along a corridor. They were separated by plywood walls (190 cm high) allowing the different groups auditory but no visual contact. Fresh air was introduced above the plywood walls. Spent air was removed from each pen by a separate duct. Each pen was illuminated by an incandescent light bulb (75 W). In addition, there was a fluorescent tube (36 W) per 2 pens. Light intensity at the height of the animals was about 60 lux. Day length was 13 h (between 05·30 and 18·30 h) for the first 3 and a half weeks. In the following week, day length was gradually increased to 16 h (between 04·00 and 20·00 h) and then kept constant until the end of the experiment. At the beginning and the end of the day there was a 15 min twilight phase.

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. A feeding trough (diameter 30 cm) was suspended in the front area next to the glass door. Two cup drinkers were installed in the rear area. A nest box (50 × 40 cm, height 40 cm) with plastic curtain and alighting board, containing chaff was fixed to the rear wall (80 cm above floor level). A perch (210 cm long) was provided in each pen at 77 cm above the floor.

Pen floors at the front (100 × 90 cm) were of slats (width 1 cm, 2·5 cm apart, 30 cm above the ground) whereas rear floors (165 × 90 cm) were varied. In 8 pens the rear floor was also slatted whereas in the other 8 it was covered with long-cut straw about 5 cm thick to promote foraging behaviour, and was about 25 cm lower than the slats in the front. As a 2nd factor food form was varied with mash in 8 pens and pellets (diameter 4·7 mm), in 8. Nutritional composition was identical: 17·5% crude protein, 4·0% crude fibre, 11·7 MJ metabolisable energy/kg.). Access was *ad libitum*. Foraging material and food form were varied as independent factors, giving 4 housing conditions (mash/straw, mash/no straw, pellets/straw and pellets/no straw). The row of 16 pens was subdivided into 4 blocks, and the 4 housing conditions were assigned at random to the 4 pens of each block.

Procedures

All hens were marked individually with coloured leg rings. Feeding troughs were refilled every 2nd day. To keep the straw dry and attractive to the hens it was replaced or added to whenever necessary. Pens were entered for daily egg collection. All regular procedures were carried out between 17·00 and 18·30 h.

To avoid unnecessary pain, all injuries caused by feather pecking were treated with tar. This effectively prevented other hens from pecking at the wounds. Bloody injuries were found in 13 animals. No animal died during the experiment but one hen was toe-pecked and had to be removed in week 25. Another hen was removed from her group in week 20, because of persistent aggression from her pen mates. The experiment was subjected to the authorisation procedure prescribed by the Swiss Animal Welfare Legislation (application No. 91/96).

Behavioural observations

Data collection by two persons, ran from week 19 to week 25. Hens were observed 4 times a week on 4 different days, twice in the morning between 09·00 and 12·00 h and twice in the afternoon between 14·00 and 17·00 h.

Sampling was similar to previous studies with chicks (Huber-Eicher and Wechsler, 1997, 1998) and hens (Wechsler and Huber-Eicher, 1998). During the observations as a given day all occurrences (Altmann, 1974) of feather pecking interactions in a group were recorded (using a PC) for 3 periods of 4·5 min each. Aggressive pecks were ignored. Feather pecks successively directed at the same receiver were recorded as 1 interaction. An interaction ended when there were no pecks for 4 s. Pecks at legs, beaks, combs or wattles were ignored, as such pecks may be under the control of another behaviour system and not linked to feather pecking. There was no statistically significant observer effect on the rate of recorded feather pecking interactions (t test for matched samples; $t=1·67$, $P>0·11$).

Every feather pecking interaction was attributed to 1 of the following 4 types of behaviour (increasing intensity): 1) pecking a feather without pinching, 2) pinching a feather and pulling weakly, 3) pulling at a feather with a vigorous backward movement of the head and 4) plucking a feather. Interactions composed of repeated pecks were classified according to the most intense behaviour observed.

During the 30 s following each 4·5 min period of data collection on feather pecking the activity (foraging, feeding, dustbathing, preening and moving) and the location (on the floor, on the perch) of all hens of a pen were recorded (scan sampling; Altmann, 1974). The activities were defined as follows. Foraging: the hen is pecking at the floor or at other parts of the pen (but not at the food) or it is standing/moving with its head in a lower position than the rump. Feeding: the beak is within 5 cm of the food. Preening: the hen is nibbling, stroking or combing the plumage with the beak (Kruijt, 1964). Dustbathing: the hen shows vertical wing-shaking

or has shown vertical wing-shaking before the scan, and has not yet finished this dustbathing bout by body/wing-shaking (Kruijt, 1964) in a standing position or moving away from the dustbathing site. Moving: the hen shows locomotion without foraging.

Focal animal observations were carried out to investigate behaviour around the feeding trough in more detail. For data collection the software system, The Observer 3·0 (Noldus Information Technology, Wageningen, NL), was used and observations were by 1 person between 12·00 and 14·00 h on 4 d a week from week 20 to week 25. At least 1 focal animal observation was made of each hen within this period, the number of protocols per pen varying between 14 and 18. To achieve even distribution no more than 2 hens were observed per pen and d. A protocol started with the 1st peck into the food of a hen that had not fed for the last 3 min. The protocol was discarded if there were fewer than 5 feeding pecks or if a disturbance interrupted food pecking for more than 30 s. A protocol ended when there were no feeding pecks for 1 min or if the hen moved more than 50 cm away from the feeding trough.

The following mutually-exclusive behavioural elements were recorded during the focal animal samples: feeding, foraging, preening, scratching and agonistic interaction. A feeding bout started with the 1st food peck and lasted to the start of a different activity. During a feeding bout food pecks were counted. The focal animal was recorded as foraging when its beak was within 5 cm of an object other than food and as scratching when it made backward strokes of the leg on the slats or the rim of the feeding trough. Agonistic interactions included pecking as well as ducking or escaping in response to a peck.

Feather damage

The plumage was scored for damage when the hens were 27 weeks old, using a scoring system of 1 (perfect plumage), 2 (feathers damaged, no skin area denuded), 3 (denuded area up to 3×3 cm) or 4 (denuded area greater than 3×3 cm) points for 6 individual parts of the body: breast, leg, vent, back, rump, wings. In addition, the tail was given a score of 1 (perfect), 2 (damaged) or 3 (feathers missing). A total feather damage score was calculated for each hen by adding the 7 scores (range 7 to 27 points).

Statistical analysis

The pens were treated as independent observational units. The analyses were performed using Systat (Wilkinson, 1992) and Microsoft Excel. All statistical tests are 2 tailed with an alpha level of 0·05. Data from weeks 19 to 25 were combined and analysed using a 2-way ANOVA with foraging material and food form as main factors. Because hens in the nest boxes were not visible, the rate of feather pecking interactions for a given pen was divided by the average number of hens visible in the scan samples for that pen.

Prior to the ANOVA, square-root and arcsine square-root transformations (Sokal and Rohlf, 1981) were applied to rates and percentages, respectively, to achieve normal distribution of the residuals (Lilliefors, 1967). Square-root transformations were also applied to the total feather damage scores. Untransformed data are given in the Tables and the Figures.

RESULTS

The 2 factors, varied in the housing conditions, had the intended effects on foraging and feeding behaviour. A significantly higher proportion of hens was recorded as foraging in pens with straw than without (Table 1) and the percentage of time spent feeding was significantly increased in groups fed on mash compared to those fed on pellets, both in the scan (Table 1) and the focal animal samples (Table 2).

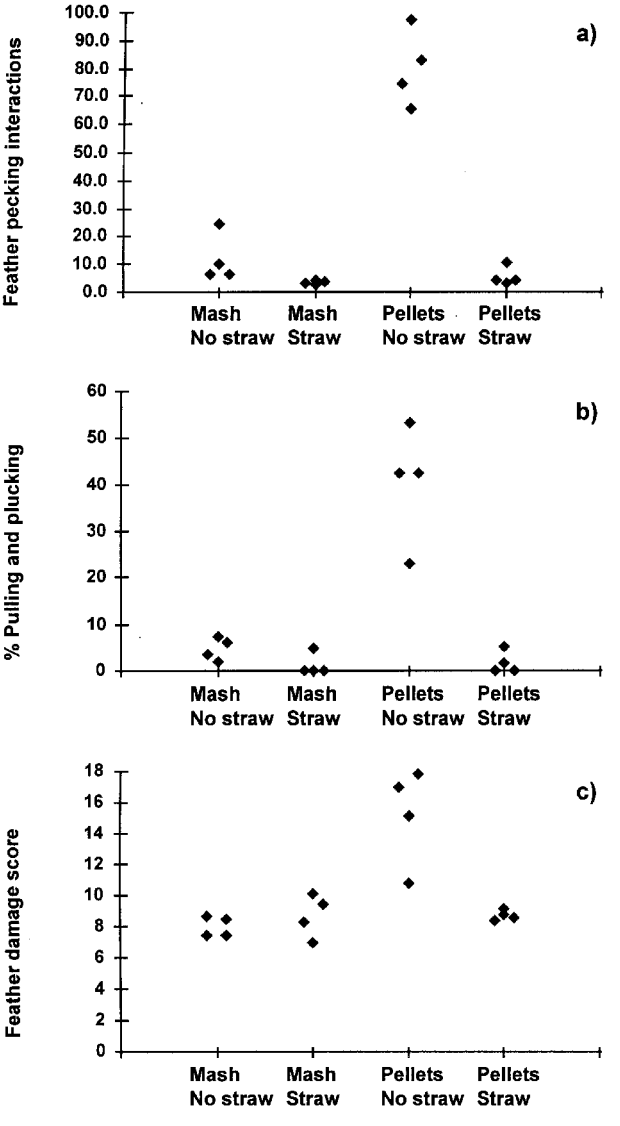

Figure. *Effects of foraging material (long-cut straw) and food form on (a) rates of feather pecking interactions (per 11 hens per 60 min), (b) percentages of feather pecking interactions classified as pulling or plucking and (c) total feather damage scores. Group means are given.*

Table 1. *Effects of foraging material and food form on the percentages of hens engaged in different activities in scan samples. Means as well as minimum and maximum values (in parentheses) of 4 pens per housing condition, P values derived from ANOVA*

Behaviour	Housing conditions				*P* values		
	Pellets/straw	Mash/straw	Pellets/no straw	Mash/no straw	Foraging material	Food form	Interaction
Foraging	31·3 (23·3, 37·8)	22·4 (15·3, 28·8)	10·3 (8·7, 12·1)	8·8 (6·5, 10·6)	<0·0001	<0·05	NS
Feeding	17·1 (15·6, 20·7)	29·3 (25·3, 32·4)	18·2 (16·1, 21·3)	32·3 (28·3, 35·4)	NS	<0·0001	NS
Preening	2·1 (1·6, 3·5)	1·7 (1·4, 1·9)	4·8 (2·6, 6·6)	2·8 (1·9, 3·1)	<0·002	<0·05	NS
Dustbathing	2·1 (1·0, 3·9)	3·1 (1·8, 5·7)	0·2 (0, 0·6)	0·3 (0, 0·6)	<0·0001	NS	NS
Moving	2·0 (1·5, 3·2)	1·6 (1·3, 2·0)	4·7 (2·4, 6·8)	2·7 (1·8, 3·1)	<0·002	<0·05	NS
Perching	16·4 (8·3, 27·4)	13·3 (6·1, 22·8)	34·2 (26·1, 40·3)	19·7 (19·1, 20·5)	<0·005	<0·03	NS

Table 2. *Effects of foraging material and food form on food pecking rates (per individual and per 30 s feeding), duration of feeding bouts (s), percentage of time spent in different activities next to the feeder and rates of agonistic interactions (per individual and per 30 s) in the focal animal samples. Average values as well as minimum and maximum values (in parentheses) of 4 pens per housing condition, P* values derived from ANOVA

Behaviour	Housing conditions				*P* values		
	Pellets/straw	Mash/straw	Pellets/no straw	Mash/no straw	Foraging material	Food form	Interaction
Food pecking rate	27·2 (25·4, 28·7)	34·6 (30·9, 38·7)	24·6 (21·1, 27·8)	37·2 (33·7, 42·4)	NS	<0·0001	NS
Feeding bouts	19·3 (13·2, 29·4)	36·2 (29·3, 41·8)	15·1 (11·8, 19·4)	38·2 (27·9, 45·9)	NS	<0·0001	NS
Feeding	54·8 (51·0, 59·0)	70·1 (64·3, 75·0)	51·9 (46·9, 57·2)	76·1 (68·3, 90·4)	NS	<0·001	NS
Foraging	3·5 (2·3, 5·9)	0·7 (0·1, 1·4)	5·6 (4·3, 7·6)	0·4 (0, 1·3)	NS	<0·0001	NS
Preening	3·6 (0·7, 9·1)	0·9 (0·1, 2·3)	4·5 (1·3, 7·5)	0·5 (0, 1·8)	NS	<0·01	NS
Scratching	0·1 (0, 0·2)	0 (0, 0·1)	0 (0, 0·1)	0·1 (0, 0·3)	NS	NS	NS
Agonistic interaction	0·2 (0·1, 0·3)	0·3 (0·2, 0·4)	0·3 (0·2, 0·5)	0·2 (0·1, 0·5)	NS	NS	NS

The rate of feather pecking interactions (per 11 hens per 60 min) varied between 2·5 and 97·2 (Figure a). Both foraging material ($F_{(1,12)}$ = 114·01, P<0·0001) and food form ($F_{(1,12)}$=62·81, P<0·0001) had significant effects on feather pecking and there was also a significant interaction between these 2 factors ($F_{(1,12)}$=45·96, P<0·0001). This interaction reflects the fact that high rates of feather pecking were only observed in pens in which the hens were housed without access to straw and fed on pellets. Corresponding significant effects were found with the percentages of feather pecking interactions classified as pulling or plucking (foraging material: $F_{(1,12)}$=48·50, P<0·0001; food form: $F_{(1,12)}$=22·23, P<0·0001; interaction: $F_{(1,12)}$= 16·53, P<0·002; Figure b) and with the total feather damage scores (foraging material: $F_{(1,12)}$=10·63, P<0·007; food form: $F_{(1,12)}$=18·19, P<0·002; interaction: $F_{(1,12)}$=17·68, P<0·002; Figure c). In groups characterised by high rates of feather pecking the hens also showed more severe forms of this behaviour, and feather damage scores were markedly increased.

Table 1 shows that not only foraging material but also food form had a significant effect on foraging in the scan samples. The behaviour was more often observed in hens fed on pellets than in those fed on mash. Food form but not foraging material had a significant effect on time spent feeding. Preening was significantly more often recorded in pens without straw than with and more often in hens fed on pellets than in hens fed on mash. A more detailed analysis showed that the 2 main factors had no significant effects on the proportion of hens situated on the perch that were recorded as preening (foraging material: $F_{(1,12)}$=1·29, P=0·27; food form $F_{(1,12)}$=0·56, P=0·47). With hens on the floor, on the other hand, there was a tendency for preening to account for a relatively higher proportion of the time budget in hens fed on pellets than mash (average values 9·0% and 6·2%, respectively; $F_{(1,12)}$=4·74, P<0·051), whereas foraging material had no significant effect on preening in these birds either ($F_{(1,12)}$ = 1·20, P=0·29). Dustbathing was significantly more often observed in pens with

straw than without but not significantly influenced by food form. The percentages of hens engaged in moving and perching in the scan samples were significantly higher in groups fed on pellets and in pens without straw.

Table 2 shows the effects on behaviours in the focal animal samples. Food pecking rates were significantly increased and feeding bouts significantly longer in hens fed on mash compared to hens fed on pellets. On the other hand, the percentages of time spent foraging and preening next to the feeding trough were significantly increased in pens with pelleted food. With regard to scratching and agonistic interactions there were no statistically significant differences between the housing conditions. Foraging material had no significant effect at all on the behaviour recorded in the focal animal samples.

DISCUSSION

The differences observed between housing conditions in the rates of feather pecking interactions, the percentages of interactions classified as pulling or plucking (severe pecks) and feather damage are best explained by the significant interaction effects found between 'foraging material and food form'. Feather pecking was only pronounced if the hens were both housed without access to long-cut straw and fed on pellets. Hughes (1982) published a speculative diagram showing the additive nature of various factors leading to feather damage and suggested that pecking damage is only seen when the birds' tendency to feather peck reaches a threshold. Taking this diagram as an explanatory model, our results suggest that lack of foraging material or pelleted food alone do not result in a significant increase in the hens' motivation to direct pecks at the feathers of pen mates. When these 2 factors are combined, however, feather pecking is regularly observed. In line with this model, food form (mash or pellets) had no significant effect on feather pecking in pullets kept in pens with litter-covered floors (Savory and Mann, 1997), whereas significant effects of foraging material on feather pecking were found in studies in which the birds were fed on pellets (Huber-Eicher and Wechsler, 1997, 1998; Wechsler and Huber-Eicher, 1998).

In the present study, hens showing high rates of feather pecking spent relatively little time both on foraging behaviour and on feeding. It may therefore be concluded that the behaviour systems for both foraging and feeding are involved in the development of feather pecking. However, it should be considered that feeding in the scan samples was defined by spatial proximity to the feeding trough (beak within 5 cm of the food) and not by the behaviour the hens actually directed to the food, which may have been not only food intake but also exploratory and manipulative foraging behaviour. In fact, there were indications that part of the time when hens fed on mash was recorded as feeding should have been classified as foraging. Primarily, foraging behaviour was not only influenced by provision of long-cut straw but also by food form. Hens fed on mash showed significantly less foraging behaviour than those fed on pellets both in the scan samples and in the focal animal samples. Furthermore hens fed on mash spent more time on feeding in pens without straw than with it. This trend was also present both in the scan samples and in the focal animal samples.

The percentage of hens recorded as perching in the scan samples was influenced both by provision of foraging material and food form. Hens in pens without straw and with pelleted food spent most time on the perches. They probably found the floor unattractive, as they had no access to foraging material and their time spent on feeding was reduced. Moreover, they may have learned to use the perches to avoid feather pecks, which occurred at high rates and in severe forms in these pens. In a previous study with similar housing conditions, we found that most feather pecks (85%) were addressed to hens situated on the floor (Wechsler and Huber-Eicher, 1998).

In accordance with other studies (Jensen *et al.*, 1962; Savory, 1974; Savory and Mann, 1997) time spent feeding was reduced in hens fed on pellets compared to those fed on mash. In addition, hens fed on mash had longer feeding bouts and higher rates of pecking into the food than hens fed on pellets. The time spent on scratching did not differ significantly between housing conditions and probably has no influence on the incidence of feather pecking (Huber-Eicher and Wechsler, 1998).

Duncan and Wood-Gush (1972) observed displacement preening in food thwarting situations and interpreted this behaviour as a sign of frustration. In the present study, hens fed on pellets showed significantly more preening next to the feeder in the focal animal samples than hens fed on mash. The same tendency was found in the scan samples with hens on the floor, whereas food form had no significant effect on preening in hens on perches. It is possible that hens fed on pellets were frustrated, because this food form elicits little pecking and results in short feeding bouts. Because there was no effect of food form on the incidence of agonistic interactions at the feeder, the differences in preening observed between hens fed on pellets and mash cannot be explained by differences in frustration related to competition for access to the food.

As with previous studies (Wechsler *et al.*, 1998; Wechsler and Huber-Eicher, 1998) hens in pens with high rates of feather pecking also showed more severe forms of this behaviour. It is therefore important to keep feather pecking rates low to avoid feather damage and pecking injuries (Huber-Eicher and Wechsler, 1997, 1998). As regards housing conditions: hens housed without foraging material should be fed on mash and hens fed on pellets should

be provided with adequate foraging material. However, factors other than foraging material and food form also have an influence on feather pecking such as light intensity (Hughes and Duncan, 1972), stocking density (Ouart and Adams, 1982), group size (Hughes and Duncan, 1972), fear (Craig *et al.*, 1983; Vestergaard *et al.*, 1993) and genetic variation (Cuthbertson, 1980; Ouart and Adams, 1982; Craig and Lee, 1990; Blokhuis and Beuving, 1993; Kjaer and Sørensen, 1997; Walser, 1997). If the effects of these factors are additive, as suggested by the model of Hughes (1982), all measures should be taken to keep the hens' tendency to feather peck below the critical threshold. We therefore recommend providing laying hens with foraging material and feeding them on mash as well.

ACKNOWLEDGEMENTS

We are grateful to the Federal Veterinary Office of Switzerland, the Schweizer Tierschutz STS, the Kanton Zürich and the Meta und Willi Eichelsbacher Stiftung for their financial support of the research project (No. 014·94·1). We also would very much like to thank Rolf Eggler, Peter Stettler and Christian Stettler for their practical assistance. Heinz Richner and Beat Huber-Eicher made valuable comments on the manuscript.

REFERENCES

Allen, J. & Perry, G.C. (1975) Feather pecking and cannibalism in a caged layer flock. *British Poultry Science*, **16:** 441–451.

Altmann, J. (1974) Observational study of behavior: sampling methods. *Behaviour*, **49:** 227–267.

Appleby, M.C. & Hughes, B.O. (1991) Welfare of laying hens in cages and alternative systems: environmental, physical and behavioural aspects. *World's Poultry Science Journal*, **47:** 109–128.

Bearse, G.E., Berg, L.R., McClary, C.F. & Miller, V.L. (1949) The effect of pelleting chicken rations on the incidence of cannibalism. *Poultry Science*, **28:** 756.

Blokhuis, H.J. (1986) Feather-pecking in poultry: its relation with ground-pecking. *Applied Animal Behaviour Science*, **16:** 63–67.

Blokhuis, H.J. & Arkes, J.G. (1984) Some observations on the development of feather-pecking in poultry. *Applied Animal Behaviour Science*, **12:** 145–157.

Blokhuis, H.J. & Beuving, G. (1993) Feather pecking and other characteristics in 2 lines of laying hen, in: Savory, C.J. & Hughes, B.O. (Eds) *Proceedings of the 4th European Symposium on Poultry Welfare*, pp. 266–267 (Potters Bar, Universities Federation for Animal Welfare).

Craig, J.V. & Lee, H.-Y. (1990) Beak trimming and genetic stock effects on behavior and mortality from cannibalism in white leghorn-type pullets. *Applied Animal Behaviour Science*, **25:** 107–123.

Craig, J.V., Craig, T.P. & Dayton, A.D. (1983) Fearful behavior by caged hens of 2 genetic stocks. *Applied Animal Ethology*, **10:** 263–273.

Cuthbertson, G.J. (1980) Genetic variation in feather-pecking behaviour. *British Poultry Science*, **21:** 447–450.

Duncan, I.J.H. & Wood-Gush, D.G.M. (1972) Thwarting of feeding behaviour in the domestic fowl. *Animal Behaviour*, **20:** 444–451.

Hoffmeyer, I. (1969) Feather pecking in pheasants—an ethological approach to the problem. *Danish Review of Game Biology*, **6:** 1–36.

Huber-Eicher, B. & Wechsler, B. (1997) Feather pecking in domestic chicks: its relation to dustbathing and foraging. *Animal Behaviour*, **54:** 757–768.

Huber-Eicher, B. & Wechsler, B. (1998) The effect of quality and availability of foraging materials on feather pecking in laying hen chicks. *Animal Behaviour*, **55:** 861–873.

Hughes, B.O. (1982) Feather pecking and cannibalism in domestic fowls, in: Bessei, W. (Ed) *Disturbed Behaviour in Farm Animals*, pp. 138–146 (Stuttgart, Ulmer).

Hughes, B.O. & Duncan, I.J.H. (1972) The influence of strain and environmental factors upon feather pecking and cannibalism in fowls. *British Poultry Science*, **13:** 525–547.

Jensen, L.S., Merrill, L.H., Reddy, C.V. & McGinnis, J. (1962) Observations on eating patterns and rate of food passage of birds fed pelleted and unpelleted diets. *Poultry Science*, **41:** 1414–1419.

Kjaer, J.B. & Sørensen, P. (1997) Feather pecking behaviour in White Leghorns, a genetic study. *British Poultry Science*, **38:** 333–341.

Kruijt, J.P. (1964) Ontogeny of social behaviour in Burmese red junglefowl (*Gallus gallus spadiceus*). *Behaviour Supplement*, **12:** 1–201.

Lilliefors, H.W. (1967) On the Kolmogorov-Smirnov test for normality with mean and variance unknown. *Journal of the American Statistical Association*, **64:** 399–402.

Nørgaard-Nielsen, G., Vestergaard, K. & Simonsen, H.B. (1993) Effects of rearing experience and stimulus enrichment on feather damage in laying hens. *Applied Animal Behaviour Science*, **38:** 345–352.

Ouart, M.D. & Adams, A.W. (1982) Effects of cage design and bird density on layers. 1. Productivity, feathering and nervousness. *Poultry Science*, **61:** 1606–1613.

Savory, C.J. (1974) Growth and behaviour of chicks fed on pellets or mash. *British Poultry Science*, **15:** 281–286.

Savory, C.J. & Mann, J.S. (1997) Behavioural development in groups of pen-housed pullets in relation to genetic strain, age and food form. *British Poultry Science*, **38:** 38–47.

Simonsen, H.B., Vestergaard, K. & Willeberg, P. (1980) Effect of floor type and density on the integument of egg-layers. *Poultry Science*, **59:** 2202–2206.

Sokal, R.R. & Rohlf, F.J. (1981) *Biometry*, 2nd edn (New York, W.H. Freeman and Company).

Vestergaard, K.S., Kruijt, J.P. & Hogan, J.A. (1993) Feather pecking and chronic fear in groups of red junglefowl: their relations to dustbathing, rearing environment and social status. *Animal Behaviour*, **45:** 1127–1140.

Walser, P.T. (1997) Einfluss unterschiedlicher Futterzusammensetzung und -aufarbeitung auf das Auftreten von Federpicken, das Nahrungsaufnahmeverhalten, die Leistung und den Gesamtstoffwechsel bei verschiedenen Legehennenhybriden. *Thesis*, ETH Zürich.

Wechsler, B. & Huber-Eicher, B. (1998) The effect of foraging material and perch height on feather pecking and feather damage in laying hens. *Applied Animal Behaviour Science*, **58:** 131–141.

Wechsler, B., Huber-Eicher, B. & Nash, D.R. (1998) Feather pecking in growers: a study with individually marked birds. *British Poultry Science*, **39:** 178–185.

Wennrich, G. (1975) Studien zum Verhalten verschiedener Hybrid-Herkünfte von Haushühnern (*Gallus domesticus*) in Bodenintensivhaltung mit besonderer Berücksichtigung des aggressiven Verhaltens sowie des Federpickens und des Kannibalismus. 5. Mitteilung: Verhaltensweisen des Federpickens. *Archiv für Geflügelkunde*, **39:** 37–44.

Wilkinson, L. (1992) *Systat: The System for Statistics* (Evanston, Illinois, Systat Inc).