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Examining the relationship between different naturally-occurring maxillary beak shapes and their ability to cause damage in commercial laying hens

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ABSTRACT

1. Using chicken models to avoid unnecessary harm, this study examined the relationship between naturally-occurring maxillary (top) beak shapes and their ability to cause pecking damage.
2. A selection of 24 Lohmann Brown laying hens from a total population of 100 were sorted into two groups based on their maxillary beak shape, where 12 were classified as having sharp beaks (SB) and 12 as having blunt beaks (BB).
3. All hens were recorded six times in a test pen which contained a chicken model (foam block covered with feathered chicken skin) and a video camera. During each test session, the number of feathers removed from the model, the change in skin and block weight (proxies for tissue damage) and the percentage of successful pecks (resulting in feather and/or tissue removal) were recorded.
4. SB hens removed more feathers from the model and had a greater change in skin weight than BB hens. The mean number of pecks made at the model did not differ between the beak shape groups; however, SB hens had a greater percentage of successful pecks, resulting in feather and/or tissue removal, compared to BB hens.
5. In conclusion, SB hens were more capable of removing feathers and causing damage. Birds performed more successful pecks resulting in feather and/or tissue removal as they gained experience pecking at the model.

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Morphology; severe feather pecking; welfare; cannibalism; egg production

Introduction

Severe feather pecking (SFP) remains one of the most serious welfare concerns within the laying hen industry (Cronin and Glatz 2021). Outbreaks of the behaviour are difficult to control and can result in cannibalism and flock mortality reaching 50% or more in extreme cases (Guesdon et al. 2006). Beak treatment, whether by hot-blade or infrared technology, effectively controls the damage caused by SFP (Guesdon et al. 2006; Struthers et al. 2019). However, this practice is controversial due to its impact on bird welfare. This concern has led many (primarily European) governments to ban all forms of beak trimming or, such as in the UK, allow them only until prevention methods that are as reliable and effective are found. While hens can be successfully housed when not beak-trimmed (Kaukonen and Valros 2019; Kittelsen et al. 2022), there are sometimes increased outbreaks of SFP and concurrent mortality (Guesdon et al. 2006; Riber and Hinrichsen 2017). Appropriate housing and management help reduce the risk; however, the behaviour is still prevalent, despite 50 years of research. Therefore, other approaches to address the issue could still be beneficial.

Genetic selection of specific beak shapes could be an alternative to beak treatment. Considerable variation in beak shape exists between non-beak treated pure line flocks, and aspects of beak shape, such as the maxillary beak overhang, appear to be heritable (Icken et al. 2017; Struthers et al. 2023). Pecks made with intact beaks may be more efficient, and it has been shown that feather pulling and removal results in pain in the recipient bird (Gentle and Hunter 1990; Guesdon et al. 2006). By selecting for naturally shorter or blunter beaks, birds may be less apt to cause damage when engaging in SFP behaviour (Icken et al. 2017; Struthers et al. 2023); however, the relationship between beak shape and the ability to cause damage needs to be explored.

There is a gap in the scientific literature regarding how naturally-occurring (*i.e.*, pre-existing variations occurring without artificial manipulation) beak shapes contribute towards reducing the severity of feather pecking damage. In addition, the amount of physical damage that these different beak shapes can cause has rarely been quantified in commercial poultry. Previous work with intact beaked hens has demonstrated that damage can be significant (Guesdon et al. 2006; Riber and Hinrichsen 2017; Struthers et al. 2019); however, the predominant focus of these studies has been comparing intact *versus* beak trimmed laying hens. Infrared beak-treated hens have better feather cover and lower mortality than those with intact beaks, which suggests that beak-trimmed birds are less successful at removing feathers and damaging tissue (Morrissey et al. 2016; Riber and Hinrichsen 2017; Struthers et al. 2019).

In pure line laying hens with intact beaks, those with shorter maxillary beak overhang lengths (*i.e.*, a small difference between the maxillary and mandibular beak lengths meaning that the beak was naturally blunt) tended to have better feather cover and less mortality (Icken et al. 2017). In comparing two genetic pure lines, Struthers et al. (2023) found that hens from one line with longer and larger maxillary beaks had better feather cover and less cannibalism-related mortality than the other line. Although this appears to contrast the results of Icken et al. (2017), Struthers et al. (2023) used multivariate measures of shape to analyse only the maxillary beak, while Icken et al. (2017) used a univariate

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measurement that incorporated both the maxillary and mandibular beak. Because the mandibular beak was not analysed by Struthers et al. (2023), it cannot be concluded that the beak shapes of one pure line were blunter than the other. However, these two studies suggested that the natural beak shape variation in intact beak laying hens influences the bird's ability to inflict damage upon conspecifics.

The following study investigated the relationship between naturally-occurring beak shapes, pecking success and subsequent damage in commercial laying hens. To avoid unnecessary harm, this study utilised chicken models (foam blocks covered with feathered chicken skin) for directed pecking, rather than live birds. It was hypothesised that beak shape (with an emphasis on sharpness) is correlated to damage to the chicken model. It was predicted that hens with naturally-occurring blunter beaks would cause less damage (*i.e.*, less removal of block material, skin tissue, and feathers) than those with sharper beaks.

Materials and methods

Ethical statement

This study was reviewed and approved by the Animal Experiments Committee (POU AE 12–2022) at Scotland's Rural College (SRUC). This study was conducted in the UK under a Home Office project licence (PP4328577) and complied with UK regulations regarding the treatment of experimental animals (Home Office UK 2014).

Animals and housing

Twenty-four, 33-week-old Lohmann Brown laying hens were selected from a commercial organic layer flock. Approximately 100 hens were caught and assessed for beak shapes. The hens were sorted into two groups based on a predetermined beak overhang length. The beak overhang is defined as the difference in length between the maxillary (top) and mandibular (bottom) beak. Hens were classified as having either short beaks (SB; *i.e.*, a minimum of 3.5 mm maxillary beak overhang) or blunt beaks (BB; *i.e.*, a maximum of 1.5 mm overhang; Figure 1a,b). The minimum and maximum overhang lengths chosen in the present study were based on previous beak overhang measurements collected by the research group. The average beak overhang length for the sharp group was 2.4 cm (±0.71) and 1.8 cm (±0.59) for the blunt group. Most hens were returned to the flock, but approximately 15 to 20 hens per beak shape group were identified from the 100 assessed. These hens were separated from the larger flock, and then the final 12 hens in each group were selected from these smaller groups by choosing the hens with the longest or shortest beak overhang lengths, depending on their beak shape group.

Hens were transported to SRUC's poultry unit and housed in six floor pens (four hens per pen) for 5 weeks. Hens were assigned to their home pens based on having two SB and two BB birds per pen. Hens had *ad libitum* access to commercial layer feed (crude protein 16%, energy 11.5 MJ/kg, Farmgate layers mash, ForFarmers, Brydekirk, UK) and water *via* nipple drinkers. Hens were given a one-week acclimatisation period to their pens before habituation and testing. Prior to testing, one bird in the SB group was found dead. *Post-mortem* analysis showed an ovarian mass and peritonitis as the cause of death. The feather cover of the birds coming from the commercial farm was good, and there was no evidence of feather pecking damage. After the study, all of the hens were rehomed.

Chicken model

A chicken model was created for each hen using a foam block (23 × 11 × 8 cm; Oasis Floral Products, Kent, U.S.A.) and white-feathered chicken skin. The skins were collected from the back area of previously slaughtered white-feathered broilers. The skin was attached to the block using four screws. Before testing began, screws were placed into the foam block and then removed prior to the block being weighed to establish an initial block weight. The average block weight at the start of testing was 471 g (±127 g), and the average skin weight was 18 g (±4 g). When attaching the skin, screws were placed back into the foam block at the same places to ensure that any change in block weight as not due to the screws removing block material. For each hen, the same skin and foam block were used for each test session. If a hen removed all of the feathers from the skin, a new piece of skin was attached to the existing foam block. Only two birds (one SB and one BB) needed to have new skins attached.

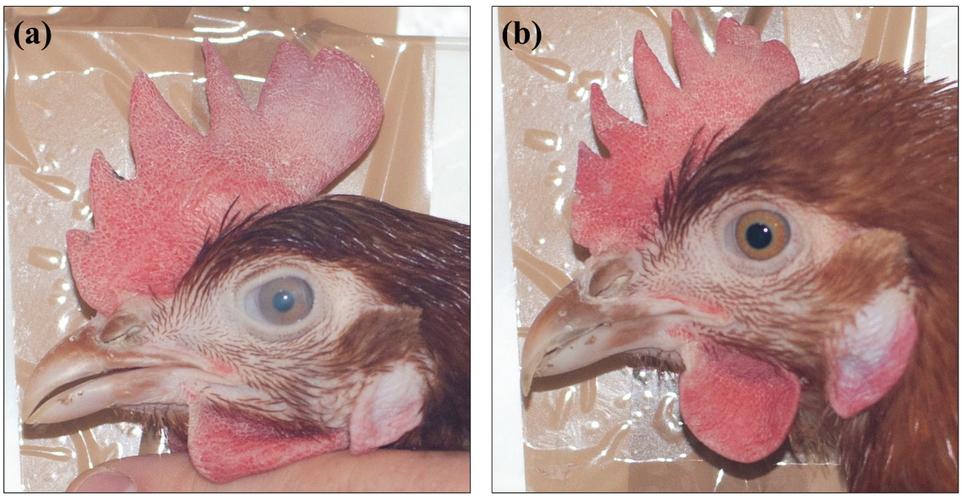

Figure 1. Representative shapes from the (a) blunt and (b) sharp-beaked groups.

Figure 2. Set up of the test pen used for the study. The black arrow indicates the chicken model (foam block covered with feathered chicken skin). The red arrow indicates the high-speed video camera.

Test pen

The test pen (0.5 m x 0.5 m) contained the chicken model (one model per hen) and a high-speed camera (GoPro HERO7, San Mateo, U.S.A.; Figure 2). Following acclimatisation to the home pen, hens were given a five-day habituation period to the test pen. During habituation, a foam block (without skin) and the camera were present in the pen. Birds did not have access to feed or water during habituation, but they had visual and audio contact with the other hens in the pens. On d 1, hens were placed into the test pen in pairs for 30 min. On d 2–5, hens were placed individually into the test pen for 15 min each day.

Following habituation, each hen was placed in the test pen and video recorded for 15 min twice a week for 3 weeks (six sessions in total per hen). All test sessions began at the same time each day and ran from mid-morning to early afternoon. Bird order was randomised so that individual birds were not necessarily tested at the same time as they had been the previous day (but could repeat time-of-day sessions in non-consecutive days). Videos were recorded in real-time at 240 frames per second (fps). Recording at this high speed enabled videos to be played back in slow motion (frame by frame) and accurately analysed pecking behaviour to determine if feather and/or tissue loss occurred.

Pecking at the model was encouraged using dried crushed meal worms, red food colouring (to imitate blood) and feed deprivation. All three methods were standardised and used for all hens. Three dried mealworms were used for each hen per test session. The worms were finely crushed and placed beneath the feathers. Four drops of food colouring were placed on top of the feathers near the quills. For three of the six test sessions per hen, the feed was removed 3 h prior to testing. Each hen could only be feed deprived three times per the project licence protocol.

Model block and skin weight change

Before and after each test session, the foam block and skin were weighed to determine weight change. Prior to weighing, the skin was detached from the foam block, and the screws were removed from the skin. The foam block and skin were weighed separately using an electronic scale (accurate to three decimal points). Since pecking resulted in block material and skin tissue removal, the block and skin weight changes were used as a proxy for potential tissue damage.

Feather removal

Before and after each test session, all remaining feathers attached to the skin were counted to determine feather removal. Feather damage (with or without removal) was not quantified.

Pecking behaviour and success

A few birds pecked at the model during test sessions one ($n = 6$) and six ($n = 4$), so these two sessions were removed from statistical analysis. For the remaining four test sessions (two to five), videos for each hen were watched for their entire duration, and the number of successful pecks (directed at the model resulting in feather and/or tissue removal) was recorded. The same observer was used for video analysis and were blinded to treatment. The high frame rate (240 fps) allowed videos to be watched in slow motion and made it easy to distinguish when feathers and tissue were removed from the skin. The percentage of successful pecks during each 15 min session was then calculated per bird.

Statistical analyses

The data were analysed as a linear mixed model with beak shape, test session (2–5 only), and their interaction as fixed effects. Bird was fitted as a random effect, which allowed for correlations in observations on the same bird. Prior to the analysis, all data were checked for normality. Block weight change, skin weight change and feather removal data were log-transformed. The data were analysed using PROC MIXED (bird as replicate unit) in SAS 9.4® (Cary, NC). Treatment differences were determined using least-square means. Differences were considered significant when $p \leq .05$.

Results

Model block and skin weight change

Beak shape had no effect on the amount of foam block material removed from the model ($p = 0.57$, d.f. = 54, F = 0.33; Table 1). However, the change in skin weight was different between the two beak shape groups ($p = 0.01$, d.f. = 34, F = 7.84), despite SB hens only having a 0.29 g larger reduction in skin weight than BB-birds. The change in block weight decreased over the four test sessions analysed ($p = 0.01$, d.f. = 54, F = 4.38; Table 1) with the highest change in weight being in session two and the lowest in session five. Test session had no effect on the change in skin weight.

Feather removal

Similar to skin weight, the total number of feathers removed from the skin differed between the two beak shape groups ($p = 0.04$, d.f. = 54, F = 4.59; Table 1). The SB hens removed an average of five more feathers from the model compared to BB hens. There was an effect of test session, with more

Table 1. The effect of shape[1] and test session[2] on the block and skin weight change and the number of feathers removed from the chicken model by commercial laying hens ($n = 11$ and 12 for sharp and BB groups, respectively).

	Beak shape (B)			Test session (T)					B x T	
	Blunt	Sharp	*P*-value	2	3	4	5	*P*-value	*P*-value	SEM[3]
Block weight change (g)	−1.93	−1.83	0.57	2.39^{a}	1.82^{b}	1.69^{b}	1.55^{b}	0.01	0.81	0.091
Skin weight change (g)	−1.13^{b}	−1.42^{a}	0.01	1.07	1.21	1.40	1.40	0.11	0.12	0.057
Feathers removed (n)	8^{b}	13^{a}	0.04	7^{c}	8^{bc}	15^{a}	12^{ab}	0.01	0.09	1.1

[a,b,c]Means within a main effect with different superscripts are significantly different ($p \leq 0.05$). [1]BB = maximum of 15 mm top beak overhang; SB = minimum of 35 mm top beak overhang. [2]Test sessions 1 and 6 were removed from analysis due to low pecking activity. [3]Standard error of the mean.

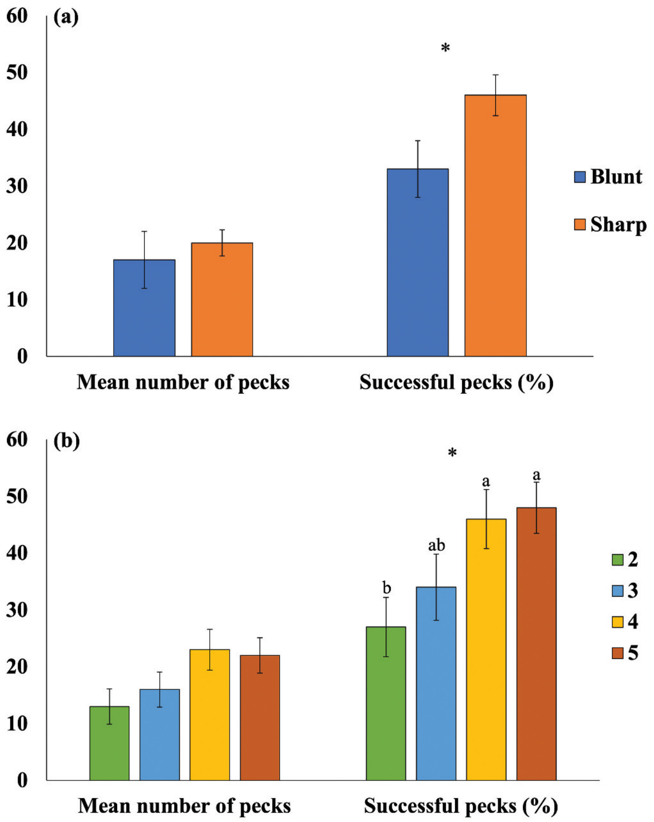

Figure 3. The effects of (a) beak shape and (b) test session (2–5) on the mean number of pecks made at the model and the mean percentage of successful pecks (resulting in feather and/or tissue removal) by commercial laying hens. Blunt beak = maximum of 1.5 mm top beak overhang; sharp beak = minimum of 3.5 mm top beak overhang. Test sessions 1 and 6 were removed from analysis due to low pecking activity. *Significantly different ($p \leq 0.05$). Error bars are ± SEM.

feathers being removed in session four compared to sessions two and three ($p = 0.01$, d.f. = 54, F = 3.97).

Pecking success

Hens with different beak shapes did not differ in the mean number of pecks made at the model per 15 min test session ($p = 0.52$, d.f. = 1, F = 0.42; Figure 3a). The mean number of pecks made at the model did not differ between the test sessions ($p = 0.27$, d.f. = 3, F = 1.34; Figure 3b). However, pecking success did differ significantly between the beak shape groups, with SB birds performing a greater percentage of successful pecks than BB birds ($p = 0.02$, d.f. = 1, F = 6.12; Figure 3a). For successful pecks, there were significant effects of test session, with hens performing a greater percentage of successful pecks in test sessions four and five than in test session two ($p = 0.04$, d.f. = 3, F = 2.97; Figure 3b). No interactions between beak shape and test session were observed for any response variables.

Discussion

This study was part of a larger project that characterised the naturally-occurring variation in laying hen beak shape and investigated the feasibility of using beak shape as a selection trait to reduce the damage inflicted during SFP (Struthers 2023). In the present study, the mean number of pecks at the chicken models did not differ between the two beak shapes; however, the percentage of pecks that resulted in successful feather removal was higher in the SB group than the BB group (46% *vs.* 33%, respectively). This was similar to results from previous studies examining SFP in beak-treated versus intact laying hens. While some studies reported that infrared beak-treated hens exhibited less feather damage by performing less SFP (Gilani et al. 2013; Hartcher et al. 2015), it may be possible that the frequency of the behaviour does not differ. Rather, the lower levels of feather damage seen in beak-treated birds are because they are less effective at causing damage (Blokhuis and Van Der Haar 1989; Lambton et al. 2010).

Icken et al. (2017) found that, as beak overhang length increased (*i.e.*, became sharper) in pure line laying hens, so did the number of feathers that were damaged or removed during pecking. The present study did not determine whether the behaviour being performed by the hens was morphologically severe feather pecks (Dixon et al. 2008). However, the focus was to determine whether certain beak shapes produced more damage, regardless of the type of peck being performed. The results of Icken et al. (2017) and the present study lend support to the hypothesis that blunter-shaped beaks are less capable at removing feathers and damaging tissue.

Previous research has suggested that the performance of SFP may be a positive experience for the pecker (Daigle et al. 2015; Harlander-Matauschek et al. 2008; Kjaer and Sørensen 1997). This positive feedback (feathers, tissue or blood) may result in prolonged and ultimately damaging pecking; however, the results of the present study do not support this, as both beak shape groups pecked similarly, irrespective of the number of feathers removed. Using an inanimate model versus a live bird as the pecking recipient may help explain the lack of difference in the number of pecks made. It is possible that BB hens pecked at the model as much as SB hens simply because the model was stationary and constantly present, whereas a live bird could react and move away.

Pecking success rate increased with test session, which suggested that, as birds gained experience with pecking at the model, they became more successful at removing feathers and/or tissue. It has been suggested that chickens, like many other species, have episodic memories (the ability to remember specific past events; Marino 2017). This suggests that they perceive time intervals and can use their past experiences to anticipate future events (Marino

2017; Zimmerman et al. 2011). In the present study, it appeared that the hens used their experience with pecking at the model to realise that the more pecks made at the model, the higher the chance of a reward (feathers and/or skin).

Despite the small difference in skin weight change (0.29 g) between the beak shape groups in the present study, the results suggested that birds with blunter beak shapes were less able to tear and remove skin tissue. Although most of the change in skin weight in the present study is likely due to feather loss, birds in the SB group were observed tearing and consuming pieces of skin tissue. Block weight change did not differ between the beak shape groups. The foam blocks were friable, and it was hypothesised that, as birds pecked at the skin, pieces of the block underneath would break off and that SB birds would cause more pieces of foam to break off compared to BB birds. All pecks made at the blocks likely resulted in small changes in weight; however, since the mean number of pecks did not differ between the beak shape groups, there was no change in block weight. The lack of difference could be partly explained by non-pecking related damage, such as hens stepping on the blocks and removing material with their claws.

A potential limitation of the present study was that the hens were sorted into sharp *vs.* blunt groups even though, within the groups, there was variation in beak shape. The study could have incorporated other beak shape traits and performed the analysis using a continuous measure of beak shape traits rather than just for the extreme phenotypes. Using intermediate beak phenotypes may have allowed a better understanding of the relationship between beak shape and pecking damage; however, the intermediate phenotypes may not be shapes that are distinct from the two extreme phenotypes. The results of the present study suggested that there may not have been enough of a difference in the extreme beak shapes to elicit significant differences in damage; therefore, testing intermediate phenotypes would be redundant.

The results of this study demonstrated that birds with an SB shape (*i.e.*, one where the maxillary beak extends far out over the mandibular beak) may be more capable of removing feathers and/or tissue than those with a blunter beak shape. However, the results suggested that factors beyond the maxillary beak curvature (*i.e.*, sharpness), such as other beak shape traits or the motivation to perform the behaviour, may contribute to feather removal and the potential to cause tissue damage. Any relationship between naturally-occurring beak shapes and a bird's predisposition to be a feather pecker still remains to be established. Both the beak shape and the propensity to feather peck are heritable (Bennewitz et al. 2014; Cuthbertson 1980; Icken et al. 2017; Kjaer et al. 2001; Lutz et al. 2016; Struthers et al. 2023) and it would be of interest to determine whether genetic correlations exist between the two.

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No potential conflict of interest was reported by the author(s).

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Data availability statement

Video data are available from the University of Edinburgh's DataShare at https://doi.org/10.7488/ds/3838.

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