The effect of straw as environmental enrichment on welfare of laying hens, at four Herenboeren farms in the Netherlands

- July 18th, 2024 -

Utrecht University

Koen Riep
Veterinary Medicine
Utrecht University

A thesis submitted to the department of Animals in Science and Society

Supervised by Prof. dr. ir. T.B. Rodenburg and S. Kliphuis MSc.

Abstract

Animal welfare is an increasingly important theme in society, that affects and has affected many species in the way they are kept. One way to measure welfare of laying hens, is by looking at their integument (feathers and skin). An integument in bad condition indicates problems in environment, nutrition, health, or feather pecking; a problematic behaviour that increased in prevalence since laying hens are nowadays frequently held in non-caging systems. This study aimed to determine whether adding straw as environmental enrichment could reduce improve welfare of laying hens at four Herenboeren farms in the Netherlands, where hens were temporarily kept indoors due to HPAI outbreaks. Feather Scores (FS), Wound Scores (WS), Total Score (TS) (WS+FS=TS) and Total Pin Feather Scores (TPFS, to assess feather regrowth), were evaluated at three distinct time points (T1, T2, T3), on four farms. During every assessment 50 chickens were randomly selected and examined in flocks that ranged between 120 and 243 chickens. Environmental enrichment involved adding 3-5 kg of straw per square meter to the outdoor runs, after the baseline measurement at T1.

Statistical analyses using Friedman and Wilcoxon signed-rank tests showed significant improvements in all groups combined TS (P=2.785e-7), FS: (P=3.971e-5), WS (P=1.659e-10) over time, but particularly in two groups that initially showed more feather- and skin damage than the other groups. The TPFS analysis indicated clear signs of feather regeneration (P = 1.331e-6). The findings of the study support the hypothesis that states straw as environmental enrichment can significantly reduce feather damage and very likely also feather pecking behaviour. This highlights that simple modifications can improve welfare of laying hens significantly. However, limitations such as variation in farm conditions, and the short duration of the study suggest that further research with more controlled variables and longer follow-up is necessary to validate and optimize the enrichment practices.

Table of contents

Introduction

Basics of animal welfare

“Human beings have direct duties towards animals, because animals are beings that can flourish, the flourishing of animals is intrinsically or inherently valuable, and that which is conducive to their flourishing is a legitimate object of moral concern” (Heeger & Brom, 2001). This quotation is one of many, that underscores the importance of animal welfare; a principle that gained popularity after the second world war, when mass production grew at the expense of animal health and welfare. Publications such as 'Animal Machines' and 'The Brambell Report' in the 1960s highlighted the suffering of animals and the lack of animal welfare, raising public awareness and leading to greater concern for animal welfare (Harrison, 2013; Majewski et al, 2024; Sayer, 2013). Especially in the last few decades animal welfare gained popularity and attention (Majewski et al, 2024; Duncan, 2019; Rushen, 2008). Society is and has been constantly changing, nationally and internationally, and so is the role of animals within it. Animals used to be solely seen as food or instrument, with practical or sometimes symbolic use, but are nowadays considered sane beings with intrinsic value of their own, as has also been written down in Dutch- and international law (Fogle, 1999; European Parliament, 2021; Wet dieren, 2024). The livestock production industry has been significantly influenced by the adoption of animal welfare principles, which have made a lasting impact since the introduction of the ‘Five Freedoms’ in 1965 (Brambell, 1965; Webster, 2016). Brambell stated that positive animal welfare can be achieved if animals are free of 1 hunger and thirst or inadequate food, 2 thermal and physical discomfort, 3 pain, injury and disease, 4 fear and chronic stress and 5 are able to express normal, species-specific behavioural patterns (Brambel, 1965, Ohl & van der Staay, 2012). The five freedoms have persisted as foundation for newly created animal welfare benchmarks worldwide (Dermatoto et al., 2017; He et al., 2022, Majewski et al, 2024). Ohl & van der Staay have adjusted them into a more dynamic concept, that included being able to adjust and cope with negative emotions, as animals have evolved that way, leading to the line: ‘’*positive welfare implies that the animal has the freedom and capacity to react appropriately to both positive and potentially harmful (negative) stimuli, given the limits of the animals’ capacity to adapt’’ (Ohl & van der Staay, 2012).* Barnard and Hurst stated that the adaptability limits are set by the environment or evolutionary adaptedness (Barnard and Hurst, 1996). Implementing the 2012’ welfare concept into the five freedoms resulted in ‘’*An individual is in a positive welfare state when it has the freedom adequately to react to hunger, thirst or incorrect food; thermal and physical discomfort; injuries or diseases; fear and chronic stress, and thus, the freedom to display normal behavioural patterns that allow the animal to adapt to the demands of the prevailing environmental* *circumstances and enable it to reach a state that it perceives as positive'' (Ohl & van der Staay, 2012).* The Dutch government has even expanded on these foundations by incorporating six principles of animal-worthy livestock farming, which include intrinsic value and integrity, good feeding, good housing, good health, opportunities for natural behaviour, and a positive mental state. These principles were outlined in the animal-worthy livestock farming covenant (Rijksoverheid, 2023).

Not only ethical considerations highlight the importance of animal welfare. Welfare also directly influences productivity. For instance, Moura et al. (2006) found that animals in good welfare conditions showed higher production levels, and according to Fraser et al. (1997), improving the circumstances in which farm animals live can lead to better overall health and productivity. Furthermore, Broom (2001) highlights that animals in better welfare states exhibit fewer stress behaviours and increased efficiency in production systems. A state of distress, as an example of suboptimal welfare, alters any animals normal body function, which can directly lead to a reduction in production (Thaxton, 2004). Additionally, stress can impair reproductive performance, lower body weight, and suppress the immune system, emphasizing the importance of animal welfare for both the productivity of the farm and the health of the animals (Mumma et al., 2006).

Laying hen welfare

Worldwide, an increasing number of nowadays around 8 billion laying hens are kept for egg production, of which most are kept in cage systems (Ritchie, 2023; Yuhuan & Fu, 2019; Guyonnet, 2022; Eurostat, 2022). In Europe, more attention for improving animal welfare led to a ban on conventional battery cage systems on laying hen farms in 2012 (Schuck-Paim et al, 2021; European Commission, 2024; Majewski et al, 2024). A review written by Hartcher & Jones states that conventional cages cause extreme behavioural restriction, poor musculoskeletal strength and increase the risk of bone fractures in hens (Hartcher & Jones, 2017). In the EU, individual member states have implemented various bans on all types of cages, as the European Commission has committed to phasing out caged systems by 2027, to improve animal welfare standards across the EU (European Commission, 2024). Germany for instance, plans to ban enriched cages by at least 2028, while Luxembourg and Austria have already prohibited their use (European Parliament, 2020). In the Netherlands, the government has also taken steps towards improving animal welfare by implementing stricter regulations and gradually phasing out the use of enriched cages (Wet dieren, 2024). The European Commission also emphasizes the importance of providing alternative systems that enhance laying hen welfare, such as barn and free-range systems (Eurogroup for Animals, 2023; House of Commons Library, 2023; European Commission, 2024). Cage-free systems (indoor, free-range, and organic) offer more freedom of movement and possibilities to express natural behaviour (De Jong & Blokhuis, 2014). Along with that, the ban on cage systems came with an improvement of chicken welfare on different aspects, as the environment allows more natural behaviour like dustbathing, nesting, perching, social interaction, and other priority behaviours (Cooper & Albentosa, 2003; De Jong & Blokhuis, 2014). Nevertheless, housing poultry in much larger flocks also led to new welfare obstacles. Feather pecking (FP) emerged as a prevalent, hard to control and significant problematic behaviour on farms following the restriction of caging systems and is identified as the primary cause of feather damage (FD) in laying hens and can lead to cannibalism and death, severely impacting laying hen welfare (Rodenburg et al, 2005; Windhorst, 2017; Cronin & Glatz, 2020).

Feather pecking

FP can be described as pecking at- and pulling out feathers of other birds (Bilcik & Keeling, 1999; Sun et al, 2014). Pecking behaviour among birds can be divided in two distinct forms: gentle feather pecking (GFP) and severe feather pecking (SFP) (Savory, 1995; Rodenburg et al., 2013). Firstly, GFP is a type of behaviour that is believed to be functional in building social relationships, commonly observed during the rearing period (Huber-Eicher, 1999). GFP refers to pecking behaviour that causes minimal or no damage to feathers and elicits either no response or only a mild reaction from the recipient bird, but could be the cause of a more problematic behaviour (McAdie and Keeling, 2000). GFP can shift to SFP, which needs to be seen as a serious welfare and economical issue (Petek & McKinstry, 2010). On welfare aspects, SFP can cause pain, stress, injuries, increased susceptibility to disease and fear (Gentle & Hunter, 1991; Cronin & Glatz, 2020). Added to that, severe FD can lead to naked areas on the skin of the bird. These exposed areas may draw additional aggressive pecking, leading to injury, ultimately escalating to cannibalism and death of the affected bird (Blokhuis & van der Haar, 1992; Savory & Mann, 1997; McAdie & Keeling, 2000). Many studies show a high prevalence of FP on cage-free farms. For example, during one study on cage-free housing systems, researchers discovered a significant prevalence of FP, with as many as 99% of hens affected by FP and up to 12.6% by cloacal cannibalism (Gunnarsson et al., 1999). In another study on the prevalence of FP involving 630 birds housed in experimental pens, Rodenburg et al. concluded that while the majority exhibited GFP at six weeks of age, only 2% showed SFP. By the time the birds reached 30 weeks of age, SFP was observed in 15% of the birds (Rodenburg, 2005). One year later, a literature review on studies in large-scale commercial flocks indicated that 40-80% of the flocks suffered from FP (Blokhuis et al., 2007). Research conducted by Bessei & Kjaer indicates that the emergence of SFP is triggered by a small proportion of birds, which may then spread this behaviour throughout the flock easily in alternative housing systems, compared to the conventional cages (Bessei & Kjaer, 2015). Birds that experience FP are more susceptible to further pecking, cannibalism, and injuries, leading to an even further decrease in animal welfare (Campe et al., 2018).

Next to welfare issues, significant occurrence of SFP can also lead to substantial economic losses for the industry (Bilcik & Keeling, 1999; Petek & McKinstry, 2010). To start with, FP-induced cannibalism can be a cause of mortality on laying hen farms (Appleby & Hughes, 1991; Cheng 2006; Lambton et al, 2013). In cage-free systems, mortality rates can often exceed 15% or even 20% due to SFP, which is significantly higher than in cage systems (Blokhuis et al, 2005; Blokhuis et al, 2007; Rodenburg et al, 2012). During a study of deceased birds undergoing post-mortem examination in Sweden, it was found that 18.6% of mortality in indoor cage-free systems and 26.1% in free-range systems was attributed to cannibalism (Fossum et al., 2009). Added to that, Tauson & Svensson (1981) showed chickens with poor feather coverage have a lower feed conversion ratio, and Blokhuis et al. stated that they need 40% more food to maintain body temperature (Tauson & Svensson, 1981; Blokhuis et al., 2007). Furthermore, research has shown that stress, due to SFP, can lead to a reduction in both egg quality and egg weight in laying hens (Hedlund & Jensen, 2022). All in all feather-pecking stands out as a critical welfare issue among laying hens, due to its frequent incidence and damaging nature (Bestman et al., 2009; Gilani et al., 2013).

Factors that influence feather pecking

McAdie and Keeling (2000) suggested that SFP can develop from GFP, either by increased severity or increased intensity of pecks, while Nicol (2018) states that both internal and external factors, such as stress and fear, result in chickens pecking each other's feathers. Added to that, multiple other underlying causes of SFP have been extensively described in many studies over the past decades, defining FP as a multi-factorial behaviour with a range of influencing factors, under which early-life experiences, genetics, fearfulness, diet, feeding behaviour, individual bird variation and stress (Rodenburg et al, 2010; Rodenburg et al., 2013; Grams et al, 2015; Hartcher, et al., 2016; Jensen et al., 2005). Another major factor that has shown to play an important role (though not the only role) in reducing the occurrence of FP on chicken farms is environmental enrichment (Schwarzer et al., 2021; van Staaveren et al., 2021). Environmental factors that have been described as influencing factors for FP include availability of litter, stocking density, perches, feeders and drinkers, climate and amount of light, and available material to perform foraging behaviour (Bestman et al., 2009; Huber-Eicher & Sebö, 2001; Huber-Eicher & Audigé, 1999; Knierim et al., 2008; Drake et al., 2010; Lambton, 2008; Blokhuis & Arkes, 1984). Even though much research has been performed on the causes of FP behaviour, various theories on the main cause still exist, while the exact solution is still not well-described. FP is in many countries still restrained by remedial measures, such as beak trimming and reduced lighting, which address the damage caused by FP, but cannot prevent the onset of the problem (Petek & Mckinstry, 2010). Added to that, beak trimming creates welfare concerns of its own, like acute and chronic pain and beak malformations (Gilani et al., 2013; Hartcher et al., 2015; Quartarone et al., 2012). As many countries have banned beak trimming in the last decade (Switzerland, Sweden, Norway, Finland, Germany and the Netherlands), it has become increasingly important to minimize FP prevalence by addressing the cause of the problem (van Horne and Achterbosch, 2008; Petek and Mckinstry, 2010; Gilani et al., 2013; Rodenburg et al., 2013).

The importance of foraging behaviour

Four Herenboeren*, all located across the west and south of the Netherlands, were keen to know if there was anything simple they could do to maximize chicken welfare on their farms, while their chickens needed to be kept indoors due to Highly Pathogenic Avian Influenza (HPAI) outbreaks in the Netherlands, and showed or had shown signs of the presence of FP. One of the ideas to make this happen, was to add straw to the chicken runs as environmental enrichment, as literature provided promising results in comparable studies. Previously done studies on foraging behaviour have led to the so-called 're-directed pecking theory'. Blokhuis proposed that FP is likely a form of redirected ground pecking behaviour (Blokhuis, 1989). In short, the theory implicates there is a direct linkage between FP and not being able to satisfy the need to search for food. After all, on most farms nowadays laying hens get all their food from the feeding through, and so they no longer need to make an effort to find their food. When inhibiting food-searching behaviour, ground pecking may be replaced with FP (Blokhuis, 1986, Blokhuis 1989; Huber-Eicher & Wechsler, 1997). However, more recent research by Rudkin (2022) suggests that FP is not simply a redirection of the behaviour related to searching for food. Instead, it is linked to the chickens' intrinsic need for exploration and engagement with their environment. Despite this distinction, Rudkin's study supports the idea that providing environmental enrichment, such as straw or other materials, can effectively reduce FP behaviours. Given the fact that both theories implicate that environmental enrichment reduces FP, Huber-Eicher & Wechsler found that FP decreased when straw was used as environmental enrichment (Huber-Eicher & Wechsler, 1997). Moreover, evidence has been found that the risk of FP increases, when chickens cannot satisfactorily express their foraging behaviours (Blokhuis & Arkes, 1984). Another article, written by Star et al., describes FP in flocks with intact beaks decreased when black soldier larvae were added as environmental enrichment (Star et al, 2020). Furthermore, Johnsen et al. concluded that hens raised on wire floor showed poorer plumage conditions, more FP, cannibalism, and less dustbathing activity, compared to hens raised on sand and straw (Johnsen et al., 1998). Other options, like bundles of white string encourage environmental pecking, and have shown to successfully reduce FP, further confirming the link between FP and exploratory behaviour (McAdie et al., 2005).

Measuring welfare of laying hens

Measuring the welfare of chickens is crucial to ensuring their health and productivity. Many tools have been developed that can be used to evaluate laying-hen welfare. These tools use a variety of welfare indicators, such as feeding, environment, health, behaviour and productivity (Welfare Quality Network, 2009; Best et al., 2023; Wilkins et al., 2004).

In the current study, welfare was measured by a protocol, developed by the LayWel project. This protocol assesses feather scores (FS) on head & neck, back, wings, tail, breast, and abdomen, as well as wound scores (WS) on comb and rear as indicators for laying hen welfare and health status (Tauson et al., 2004). FS and WS can be affected by environmental factors, nutritional deficiencies, and management practices (Ambrosen & Peterson, 1997). However, FP is considered the primary cause of FD in laying hens (Huber-Eicher & Sebö, 2001; Bestman et al., 2009).

Aim of the study & Research goal

As four Herenboeren* needed a simple solution to improve welfare on their farms, while their chickens needed to be kept indoors due to HPAI outbreaks in the Netherlands, this study investigates the effect of straw as environmental enrichment on chicken welfare, by using the Laywel welfare assessment (Tauson et al., 2004). Because previous studies have shown a correlation between environmental enrichment and welfare status, the research question of this study was: will enriching the chicken run, by adding straw as environmental enrichment, improve welfare of mature laying hens at four Herenboeren farms in the Netherlands?

The LayWel welfare assessment provided a scoring method, in this study called total score (TS), serving as a welfare indicator. The TS was composed of a feather score (FS) and a wound score (WS). The FS provided information on FP behaviour and other factors affecting the integument, while the WS informed about aggressive pecking, cannibalism, and other causes of wounds. Additionally, a pin feather score (PFS) was included. Pin feathers are immature feathers still encased in their protective keratin sheath, resembling small pins, and are in the process of growing out. The PFS increases as feather regeneration occurs and can be seen as a precursor to the FS.

**"Herenboeren" is a growingly popular concept in the Netherlands, where individuals without farm ownership contribute a fixed monthly payment to the farmer. In exchange, they receive their share of the weekly farm production (https://herenboeren.nl/).*

Hypothesis

H0: ''The addition of straw as environmental enrichment to the chicken run after the first assessment (T1) will not result in significant differences in total scores, feather scores, wound scores, and pin feather scores of laying hens at the subsequent assessments (T2 and T3), indicating no measurable effect on animal welfare''

H1: ''The addition of straw as environmental enrichment to the chicken run after the first assessment (T1) will result in significant differences in total scores, feather scores, wound scores, and pin feather scores of laying hens at the subsequent assessments (T2 and T3), indicating a positive effect on animal welfare''

Materials and Methods

This research is an experimental longitudinal study that investigates the effects of environmental enrichment on the TS, FS, WS and PFS of chickens over time. The study involves repeated measures of the scoring methods at three distinct time points (T1, T2, T3) within several groups (A, B, C, D and Tot (all groups combined)).

Animals, housing, and management

This study did not involve any experimental-invasive procedures, and so did not require the approval of an ethics committee. The study was conducted in the Netherlands across four Herenboeren farms located in various regions of the country. These farms experienced or had experienced issues with FP and were interested in implementing a simple method to reduce the prevalence of this problem and so improve animal welfare.

The four farms all had between 120 and 243 chickens kept in different sized, but similar looking housing systems. Two farms moved their outdoor chicken run every 4-6 weeks and two farms had a permanent outdoor run, and all runs were accessible to the chickens during the study. Two different breeds were present on the farms: Lohmann Brown and Sasso Silver; chickens in all four groups were of different ages. Due to the high variety between farms, farm characteristics were not included in statistical analyses. An overview of all farm characteristics can be found in table 1. At all farms, chickens could go outside from around 9:30 AM onwards and were kept in their nighttime shelter after dusk. To minimize stress for the chickens due to the assessments, the following measures were implemented: knocking before entering, allowing the chickens to acclimate to human presence, avoiding loud noises, handling them briefly, ensuring that chickens were taken from a specific part of the coop without chasing them around, employing an easy scoring method, and conducting simultaneous measurements of feather-, skin- and pin feather score.

TABLE 1: The table provides detailed information on four groups of chickens, highlighting their housing type, chicken breed, number of animals, estimated size of free-range area, age at first visit, and amount of environmental enrichment (EE – straw) provided.

Farm	*Group*	*Housing*	*Chicken breed*	*Number of chickens*	*Estimated size of free-range area*	*Age of chickens at first visit*	*Amount of EE/ straw*	*Cockerels present*
Farm A	*Group A*	*Rotating*	*Sasso*	*240*	*50m2*	*30 weeks*	*150 kg*	*Yes*
Farm B	*Group B*	*Permanent*	*Lohmann brown*	*243*	*30m2*	*28 weeks*	*130kg*	*Yes*
Farm C	*Group C*	*Rotating*	*Lohmann brown*	*120*	*110m2*	*56 weeks*	*300kg*	*No*
Farm D	*Group D*	*Permanent*	*Sasso*	*120*	*120m2*	*21 weeks*	*300kg*	*Yes*

Environmental enrichment

After measuring **FS, WS, TS and PFS** of all flocks at T1, puddles and muddy areas were covered with sand and wood chips. Straw was evenly distributed throughout the outdoor area of the chicken runs in amounts of 3-5 kg per square meter. During every farm visit, straw was turned and stirred so fresh straw would lay on top. Wet and dirty straw was removed, and fresh straw was added, so that the environment would remain interesting and would promote foraging.

Data collection

Farms were visited at three moments during this research project, with specific dates detailed in table A1 (A in table names indicates they can be found in the appendix). During each farm visit, 50 chickens were randomly selected, picked up and individually assessed for FS, WS and PFS. Assessments were carried out as described in the next paragraph.

After the first assessment round, all farms applied straw as enrichment, as described in the 'Environmental enrichment' paragraph. It must be noted that every group was a 'control group' for itself, as the first assessment (T1) was the 'control assessment'. Subsequent assessments were done fourteen days (T2) and twenty-eight days (T3) after the first farm visit, following the same sequence. During these visits, another 50 randomly selected chickens per farm were assessed for feather, skin, and pin feather conditions.

The assessment of the plumage and skin was conducted by two master-students in Veterinary Medicine. Both students had been trained to use the LayWell assessment protocol during a class in their master degree and an extra training to master and synchronize their skills and ensure consistency in scoring. The students together assessed all chickens during the study, to get a more reliable score.

To improve randomization at every assessment, the nighttime shelter was divided into five equal parts, after which in every part 10 chickens were randomly picked up. To avoid repeated assessments of the same birds, the chickens that had already been assessed were placed in the outdoor chicken run for the duration of the assessment. After the assessment all doors were opened, and all chickens could freely go outside.

Due to a lack of information about the chickens on some farms, conducting a robust power analysis for the sample size in advance was too challenging. To bypass this issue, a sample size was selected that was definitely sufficient for making meaningful inferences about the entire population. In this study the sample size was set at 50, corresponding to at least 20% of the total amount of chickens on one farm.

Plumage- and skin assessment

The integument condition of each laying hen was assessed for damaged feathers, bald spots, and lesions, following the protocol established by Tauson et al. (2004). This assessment protocol was chosen for this study, as it combines useful parts of multiple protocols and takes less time than other protocols (roughly 30 seconds per chicken), causing less stress for all handled chickens.

Plumage condition of six body parts (BP1 - wings, BP2 - head/neck, BP3 - back, BP4 - tail, BP5- breast and BP6 - cloacae/vent) and pecking damage to skin of rear body (BP7) and comb (BP8) were given scores on an ordinal 4-point scale; ''*the higher the score is, the better the status of the integument*'' (Tauson, et al., 2004). Scores were written down, as shown in table A2. The assessment criteria that were used can be found in table 2. The scores for body parts were added to form three scores:

Total score (TS): scores of all body parts added, leading to a possible range of scores between 8 points minimum and 32 points maximum for each bird.
Feather score (FS): scores of body part 1 – 6 added, leading to a possible range of scores between 6 points minimum and 24 points maximum for each bird
Wound score (WS): scores of body part 7 & 8 added, leading to a possible range of scores between 2 points minimum and 8 points maximum for each bird

FS and WS of which TS existed were statistically analysed separately, so that the exact influence of these scores on the TS could be monitored more precisely. Main reason for this was that wound healing (of small wounds) can take up to two weeks (Katiyar, A. K. et al., 1992), and complete feather regrowth can take 6-9 weeks (Wu et al., 2021). This means feather regrowth could not possibly be completed within the time between first and last assessment round, but a potential stop of FP after first assessment could lead to a maximum WS.

TABLE 2: The scoring specifications for FS and WS range from 1 to 4, where '4' represents a perfect condition and '1' indicates the worst condition.

Feather score	4	Perfect feathering, with no sign of feather damage
	3	Slight to moderate wear. Evidence of pecking. Signs like broken feathers and noticeable feather shafts. No areas lacking feathers
	2	Areas vacant of feathers occupying less than ½ of the body part
	1	Areas vacant of feather occupying more than ½ of the body part
Wound score	4	No wounds, intact skin
	3	Few pecking wounds present, most pecking wounds seem to be recovering, most skin is intact
	2	Multiple small, fresh wounds present, skin visibly irritated, normal skin, and wounds alternately present
	1	Fresh blood, multiple fresh wounds, recovering areas and wounds are attached; normal skin is scarce, wounds of more than 1 centimeter in diameter present

Pin feathers assessment

Pin feathers were scored to increase the sensitivity of the study. A single feather could not possibly fully regrow during the time the study takes place, meaning bald spots (FS= 1 or 2) could not be fully covered (FS = 4) by the end of the study. By also scoring pin feathers, early feather regeneration would be noted, adding important information for the welfare assessment. The way pin feathers were scored can be found in table 3. Firstly PFS-letters were added to each body part-score of the laying hen assessment form and were later extracted to form a dataset on its own. For statistical analysis, PFS-letters that were given to each body part were summed up to form a total pin feather score (TPFS), using the criteria as described in table 3. PFS and TPFS were noted as shown in table A7.

It should be noted that a PFS of 0 should not be seen as 'bad', as both a fully bald chicken and a perfect scoring chicken would have the same score. Therefore, to correctly interpret the results of this score, they should be combined with the FS results as developed by Tauson, et al (2004).

TABLE 3: The scoring specifications for PFS and TPFS. PFS (A, B, C) are noted for all individual body parts. A represents. TPFS (0, 1, 2) are a result from the sum of the individual PFS.

Pin Feather Score (score given for each individual body part)	A	The assessed body part has no pin feathers
	B	At least 5, but less than 10 pin feathers can be found on this body part
	C	At least 10 pin feathers can be found on this body part
Total Pin Feather Score	2	At least one 'C' was given for any of the body parts
	1	At least one B but no C in any of the body parts
	0	All individual body part scores are 'A'

Statistical Analysis

Statistical analyses were performed using R-studio (version 2024.04.1+748) and Microsoft Excel 365.

TS, FS, WS

First, descriptive statistics were conducted for TS, FS and WS, out of which tables (A4, A5 and A6) in the appendix were made. Tables consisted of group, time point, n, mean, standard deviation, and min and max scores. All groups were noted both individually and combined. Out of the descriptive statistics tables, graphs (figure 1, 2, 3) were made to visualize development of the mean scores of all groups over time.

Normality of all scores was checked by using a Shapiro-Wilk test. A significance smaller than 0,05 was considered non-normal. If the original data had a non-normal distribution (<0,05), logarithmic-, square root- and box-cox transformations were used to see if any of those led to a normal distribution. Results were put into table A3. If a normal distribution was found after transforming the data, further analysis was carried out with the transformed data. A Friedman test was done for non-normal data and a repeated measures-ANOVA test for normal data to analyse differences for measurements of all groups (A, B, C, D and all combined) and time points (T1, T2, T3). Outcomes were put into a table 4, 5 and 6. To detect when significant differences in scores occurred between time points (T1-T2, T1-T3, T2-T3) within each group, a post-hoc Wilcoxon signed-rank test was conducted on TS, FS, and WS. This test was performed if the Friedman test showed significant results for a group, to determine more exactly when significant changes occurred. Outcomes of the Wilcoxon signed-rank test were also included in table 4, 5, and 6.

TPFS

A table (table A8) was made to clearly see the distribution of chicken-TPFS at all farms across all time points. Out of it, a stacked bar chart was made (figure 4) that visualizes data for all groups. To test changes in TPFS across time points (T1, T2, T3) and all groups (A, B, C, D, Tot), one way-ANOVA tests were performed. If the one way-ANOVA test showed a significant result for a group, a post-hoc Tukey HSD test was performed to compare T1-T2, T1-T3 and T2-3 individually. All outcomes were written down in table 7 and were considered significant at a P-value of <0,05.

Results

Total score (TS)

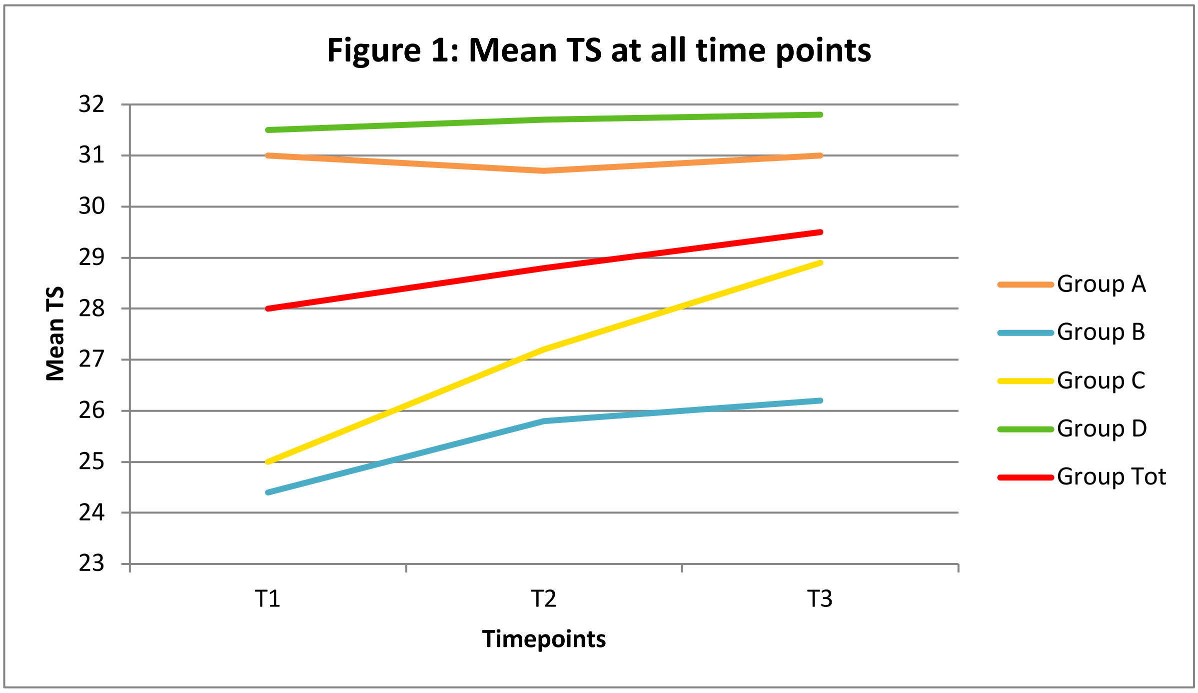


Figure 1: Mean Total scores (TS) of 50 chickens per measurement over time (T1, T2, T3). FS consists of the sum of individual scores of BP1 – BP6; WS = min 8 / max 32. Scoring method developed by Tauson et al, 2004

The graph in figure 1, made from the descriptive statistics (table A4), clearly shows an increase in mean TS over time (min = 8, max = 32) of group B (1.8pts) and C (3.9pts), D (0.3pts) and of the Tot score (mean of all groups combined, 1.5 pts). The graph also shows the consistently high score between 31 and 32 in groups A and D, as these groups hardly showed any signs of FD and pecking wounds from T1 to T3. Descriptive statistics (table A4) show small variation and standard deviation in both group A and D, and a bigger variation in all other groups, as can be noted by the steeper lines of group B, C and Tot.

A Shapiro-Wilks test showed data could not be distributed normally, even after conducting log, square-root and a box-cox transformation; no P-values showed significance (table A3).

A Friedman test (table 4) showed significant changes for group B (P = 0.016), C (P = 5.688e-7), D (P = 0.024) and Tot (2.785e-7). The TS in group A did not significantly change over time (p = 0.160). All results of the post-hoc analysis showed TS significantly improved over time in groups B, C, D and Tot, except for group B between T2-T3 (P = 0.602) and group D between T1-T2 (0.246). Overall, these groups changed with highest significance between T1-T3.

*TABLE 4: Friedman- and Wilcoxon signed rank test results for TS in all groups. Significant values are indicated by a **

	P-value – Friedman test	Wilcoxon post-hoc
Group A	0.160	-
Group B	0.016*	T1-T2: 0.032* T1-T3: 0.003* T2-T3: 0.602
Group C	5.688e-7*	T1-T2: 0.001* T1-T3: 1.44e-7* T2-T3: 0.007*
Group D	0.024*	T1-T2: 0.246 T1-T3: 0.005* T2-T3: 0.050*
Group Tot	2.785e-7*	T1-T2: 0.001* T1-T3: 1.620e-9* T2-T3: 0.006*

Feather score (FS)

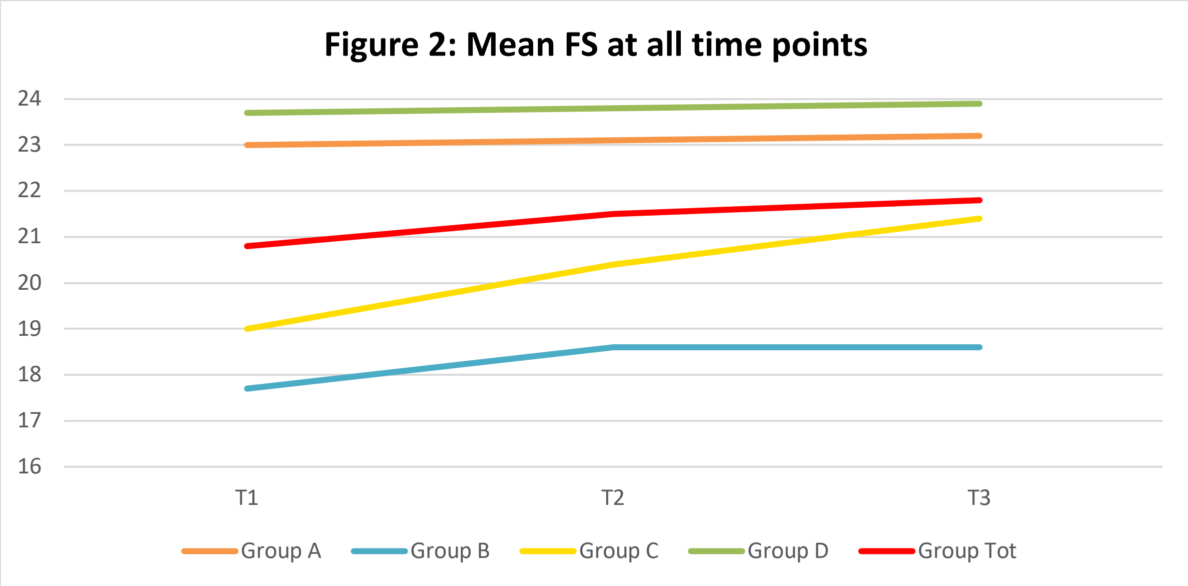


Figure 2: Mean Feather scores (FS) of 50 chickens per measurement over time (T1, T2, T3). FS consists of the sum of individual scores of BP1 – BP6; WS = min 6 / max 24. Scoring method developed by Tauson et al, 2004

The graph in figure 2, made from the descriptive statistics (table A5), shows a clear visual increase in mean FS (min = 6, max = 24) of group B (0.9 pts) and C (2.4 pts) and of the Tot score (1.0 pt). The graph also shows the consistently high score of group A and D between 23 and 24, from the beginning of the study, as these groups hardly showed any signs of FD. Both groups seem to increase to a near perfect score. Descriptive statistics (table A5) show small variation and standard deviation in both group A and D, and a bigger variation in all other groups.

A Friedman test (table 5) showed significant changes for group C (P = 4.665e-4), D (P = 0.0159) and Tot (3.971e-05). All results of the post-hoc analysis showed FS significantly improved over time in groups C, D and Tot, except for group C and D between T2-T3 (C-P = 0.059; Tot-P = 0.148) and group D between T1-T2 (0.275). Overall, all groups changed with highest significance between T1-T3. The FS in group A (P = 0.776) and B (P = 0.135) did not significantly change over time, but graph lines show an increase in mean FS.

*TABLE 5: Friedman- and Wilcoxon signed rank test results for FS in all groups. Significant values are indicated by a **

	P-value	Wilcoxon post hoc
Group A	0.776	-
Group B	0.0135	-
Group C	4.665e-4*	T1-T2: 0.005* T1-T3: 2.800e-3* T2-T3: 0.059
Group D	0.0159*	T1-T2: 0.275 T1-T3: 0.004* T2-T3: 0.034*
Group Tot	3.971e-5*	T1-T2: 0.002* T1-T3: 6.100e-4* T2-T3: 0.148

Wound score (WS)

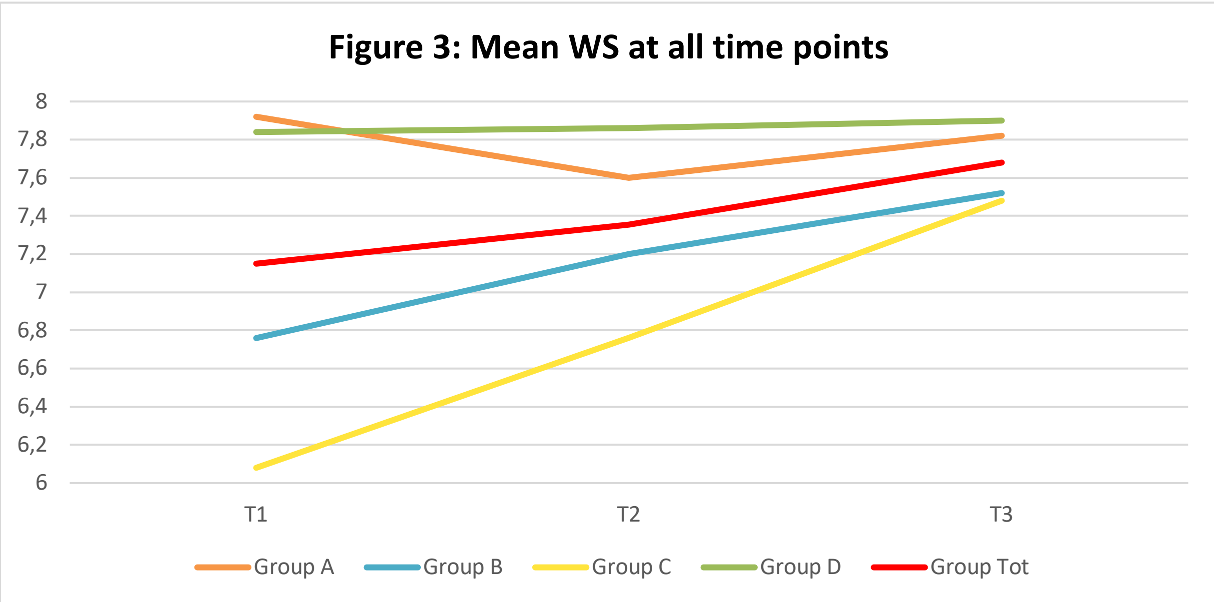


Figure 3: Mean wound scores (WS) of 50 chickens per measurement over time (T1, T2, T3). WS consists of the sum of individual scores of BP7 & BP8; WS = min 2 / max 8. Scoring method developed by Tauson et al, 2004

Descriptive statistics (table A6) reveal differences in mean WS across all groups at various time points, as is visualized by graph in figure 3. The graph shows an increase in mean WS (min = 2, max = 8) of group B (0.76 pts) and C (1.4 pts), D (0.06 pts) and of the Tot group (0.53 pts). Group D shows a near perfect score over time, while group B and C show a large improvement in score. The WS of group A decreases, and then increases again, but consistently approaches the optimum score of 8.

The Friedman test (table 6) showed significant changes for group A (P = 8.779e-4) B (P = 2.042e-6), C (P = 1.005e-9) and Tot (1.659e-10). The Wilcoxson post-hoc analysis showed WS of all groups significantly improved over time between all time points. Group A changed significantly between T1-T2 (P = 0.001) and T2-T3 (P = 0.011), but not between T1-T3 (P = 0.166).

*TABLE 6: Friedman- and Wilcoxon signed rank test results for WS in all groups. Significant values are indicated by a **

	Friedman P-value	Wilcoxon post hoc
Group A	8.779e-4*	T1-T2: 0.001* T1-T3: 0.166 T2-T3: 0.011*
Group B	2.042e-6*	T1-T2: 0.005* T1-T3: 1.470e-3* T2-T3: 0.026*
Group C	1.005e-9*	T1-T2: 0.004* T1-T3: 1.200e-5* T2-T3: 4.200e-2*
Group D	0.810	-
Group Tot	1.659e-10*	T1-T2: 0.006* T1-T3: 7.500e-7* T2-T3: 2.000e-4*

(Total) Pin Feather Score

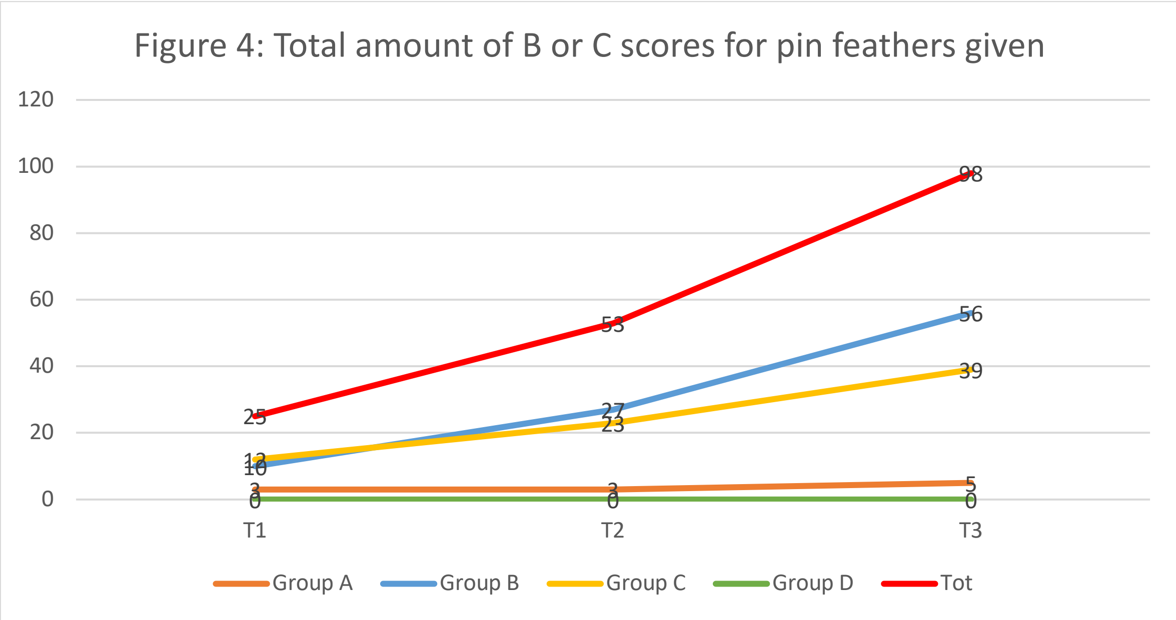


FIGURE 4: Total amount of pin feather scores B (=1) and C (=2), given for each body part (BP1-6) of each chicken (n=50) per farm and on all farms (Tot displays the total cumulative amount of body parts that show feather growth over time)

Figure 4 purely illustrates the amount of B and C scores (PFS) given to body parts of chickens over time. It is clearly visible that the number of body parts that show pin feathers increases over time, especially in group B and C.

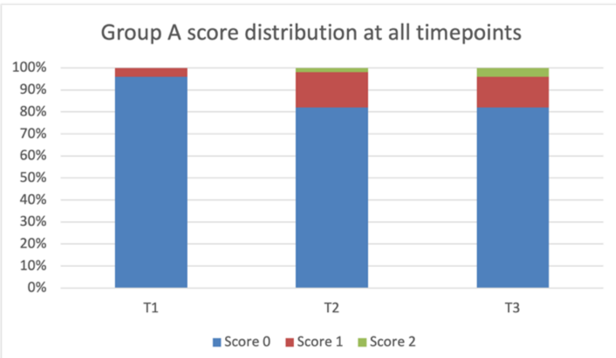
The stacked bar plots in Figure 5 illustrate the score distributions across all time points for each group. The bar plots clearly show a relative increase of scores 1 and 2 over time, while a score of 0 decreases by 50% in group B and 20% in group C, indicating feather regrowth in these groups. Table A8 shows the exact numbers of redistribution. Group A and D maintain low scores over time.

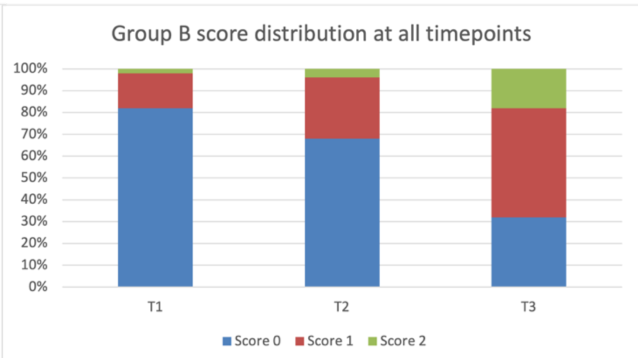
The one way-ANOVA test (Table 7) indicates a significant difference over time for both group C (P = 1,420e-7) and Tot (1.331e-6), suggesting an overall increase in pin feather regrowth in these groups. Group B shows a low P-value (P=0.066), indicating a trend towards significance. Group A shows no significant changes (P = 0.595) over time. Assessment results of group D were 100% 0 points at every measurement, so the one way-ANOVA led to no results.

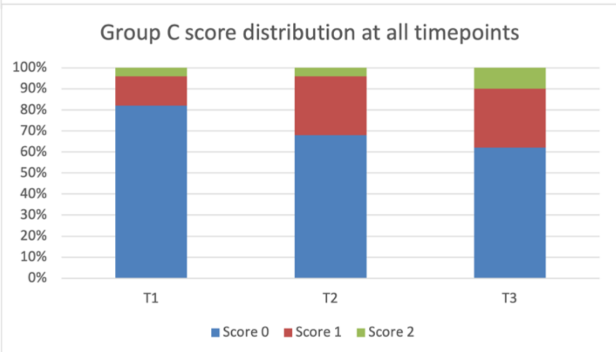
The post-hoc Tukey HSD test indicates that, for groups B and Tot, significant differences were between T1-T3 and T2-T3.

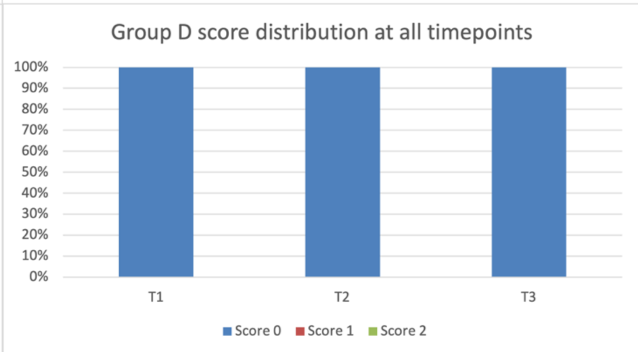
*TABLE 7: Statistical analysis of values at different time points within groups. Significant P-values are indicated by a **

Group	One way-ANOVA test result	Post-hoc Tukey HSD P-value
A	F-value: 0.521 P-value: 0.595	-
B	F-value: 17.586 P-value: 1.420e-7*	T1-T2: 0.355 T1-T3: 2.000e-7* T2-T3: 8.910e-5*
C	F-value: 2.770 P-value: 0.066*	-
D	Nan	-
Tot	F-value: 13.841 P-value: 1.331e-6*	T1-T2: 0.483 T1-T3: 2.000e-6* T2-T3: 3.540e-4*









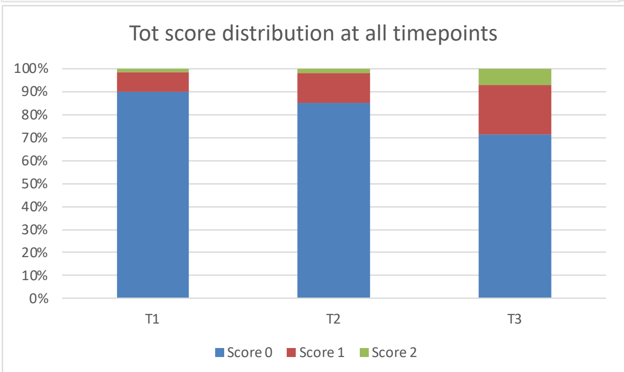


Figure 5: Bar plots illustrate relative score distributions of TPFS (0, 1, 2) for all groups at all time points (T1, T2, T3)

Discussion

The aim of this study was to see if the laying hen welfare could be increased, when the chicken run was enriched with straw. The study hypothesized that the addition of straw to the chicken run after the first assessment (T1) would result in significant differences in TS, FS, WS, TPFS of laying hens at the subsequent assessments (T2 and T3), indicating a positive effect on animal welfare. Overall, this hypothesis was based on results of studies that have been done in the past, that stated that (1). FD in laying hens is primarily caused by FP (Huber-Eicher & Sebö, 2001; Bestman et al., 2009), (2). which is a highly prevalent behaviour in cage-free systems (Gunnarson et al., 1999), and (3). could be decreased by the right environmental enrichment (Nicol et al. 2017), (4). because foraging behaviour and FP are inversely related (Huber-Eicher & Wechsler, 1998). The hypothesis of the current study was supported by the observed significant improvements in TS, FS and WS over time, particularly in groups B and C, which initially showed the lowest overall scores. The addition of straw could have provided a stimulating environment that refocused pecking behaviour from feathers to straw, reducing the incidence of SFP and so allowing feather recovery and wound healing, leading to an increased welfare at the end of the study period. The increase in TPFS over time, combined with the FS data, indicates that the intervention reduced FP and consequently facilitated feather regeneration on the farms that showed the lowest FS at first assessment. All findings align with the research by Rodenburg et al (2013), Blokhuis (1989) and Rudkin (2022) which showed that environmental enrichment can reduce FP behaviour in laying hens.

Even though the TS showed increased significantly over time, providing a generalized overview of the overall laying hens' integument improvement, the used methodology of summing up scores for all body parts to a 'TS', has some limitations which should be considered (Tauson et al, 2004, Kjaer et al., 2011). As highlighted by prior research, the scoring system that was used in the present study may not accurately reflect localized and specific types of FD, nor the multifactorial nature of feather loss (Campe et al., 2018). Such nuances are crucial because distinct risk factors typically affect different body parts. For example, FP predominantly impacts the neck, back and vent, whereas abrasions from feeding troughs primarily cause damage to the ventral neck (Bilcik and Keeling, 1999; Martin et al., 2005). Though, SFP and cannibalism could affect every body part of a chicken, as studies have extensively described in articles (Table A9 gives a clear overview of this). Even though less likely, influencing factors on TS, FS and WS like nutrient deficiency and abrasions from the environment could also have been influenced by the straw, leading to higher scores and feather regrowth (Desbruslais et al., 2021; Drake et al., 2010; Leeson & Walsh, 2004). The outcome of the used scoring methods primarily reflects feather and skin damage and should be used with caution when drawing conclusions about FP, even though FP can cause damage to any body part and is the most common cause of FD. To address this issue, a multivariate approach to analyzing FD is recommended for future research. For example, by assessing feather scores for individual body parts separately, it will be possible to more accurately identify the risk factors contributing to specific types of FD in laying hen flocks and tell more about FP behaviour.

When focussing on the TS of individual groups, the biggest increase in score could be found in the groups B and C, that both showed the lowest scores at the first assessment. Group B likely suffered from the small amount of space per chicken, which could lead to more FD and a higher incidence of FP behaviour, while laying hens in group C were over 55 weeks of age and plumage damage increases with age (Huber-Eicher & Sebö, 2001). Groups A and D hardly showed any signs of FD during first assessment, so limited score improvement was possible at those farms. According to Tauson et al (2004), a score of at least 24 points (out of 32; individual BP scores of 3-4) should be considered as a good overall score, meaning all studied groups already had an overall good score from the beginning of the research. It should be noted that there are large variations of FP influencing factors between groups in this study (table 1), and FP outbreaks are hard to predict and spread easily (Defra, 2005; Zeltner et al., 2000). The fact that there was no deterioration in scores over time in any of the groups during the study should therefore also be considered as an interesting outcome. Both more and differently affected groups should be included in future research to be able to see the effect of straw enrichment. In these groups, control groups should also be incorporated to establish a baseline for comparison and to be able to exclude external factors.

In both the WS and FS, the Tot-group and at least two other groups demonstrated significant increases in their scores over time. Specifically, in the FS setting, the group with the highest increase showed a 10% improvement from the first to the last assessment. This was less than the highest improvement observed in the WS setting, which was 17.5%. This difference was expected, as the processes of wound healing and feather regrowth occur at different rates (Katiyar et al., 1992; Wu et al., 2021). It should be noted that WS is suitable for short-term studies, like the current one. While this study showed that enrichment could significantly improve FS in only four weeks, most studies on FP follow a flock for a longer period to observe the long-term effects of their interventions (Schreiter et al., 2019). Furthermore, plumage damage is known to progressively increase until the end of the laying phase (Nicol et al., 1999; Lambton et al., 2010), so a longer research period would be needed to see the long-term effects of straw on all scores.

The self-developed PFS and TPFS showed a significant increase of early feather regrowth in two groups and has also proven its value for short term studies on feather regrowth, by showing results the FS (Tauson et al., 2004) was not sensitive enough for. Though this score has not yet been sufficiently tested and validated, leaving the possibility open that pin feathers are simply less attractive to peck at. A study by Ramadan & von Borell (2008), for example, showed that different types of feathers have varying degrees of attractiveness for feather pecking.

Furthermore, the TPFS outcome alone does not provide any information about the exact overall integument condition of the group. Therefore, the TPFS should always be used in conjunction with other feather scoring tools to accurately evaluate feather condition. The TPFS could be useful for future research, but should be further developed, so it can be implemented in, or easier used with existing feather scoring methods.

When looking at the enhancement of natural behaviour of laying hens, it is important to recognize that while straw serves as a valuable form of environmental enrichment that promotes foraging behaviour, an approach that incorporates various enrichment aspects is essential for optimal welfare (Ohl & van der Staay, 2012, Huber-Eicher & Wechsler, 1998; Hemsworth & Edwards, 2020). Another study by Son et al (2022) concluded that providing environmental enrichment materials like pumice stone and alfalfa hay improved egg production and reduced corticosterone levels in the blood, suggesting a positive influence on hen-welfare. The use of diverse enrichment elements, such as perches, nest boxes, and sand as dust-bathing substrate, lead to a broader range of natural behaviours, thereby reducing stress and the chance on SFP development, as well as promoting positive emotional states (Jung & Knierim, 2019; Olsson & Keeling, 2002; Lay et al., 2011). It is therefore important that laying hens are provided with not only straw like in this study. A variety of enrichments optimally promotes natural behaviour and additionally animal welfare improves (Nicol et al., 2017).

Variations between all groups in chicken breed, number of chickens, age, space, rotation systems, geographical location, rearing factors, and environmental enrichments made direct comparisons challenging. Other studies have shown that these elements, which were not controlled in the present study, can influence outcomes. For instance, plumage damage increases with age due to FP (Huber-Eicher & Sebö, 2001) and FP can be influenced by form and amount of free-range access (Jung & Knierim, 2018). Wide-ranging study conditions, including, stocking density, group size, fear, and genetic variation have shown to influence outcomes (Hughes & Duncan, 1972). Furthermore, including management and housing factors from the rearing phase and feed ingredient data could lead to more reliable results (Janczak & Riber, 2015). Future studies should aim for more controlled conditions across different farms to isolate and control specific factors affecting chicken welfare. Standardizing variables such as breed, feed type, space, and environmental enrichments will help in making more accurate comparisons.

Lastly, the variation in score outcomes at the farms suggests that there is considerable potential for enhancing welfare conditions at chicken farms, even at small-scale farms like Herenboeren, where chickens overall have more space compared to bigger, commercial chicken farms, where up to 9 chickens per square meter are allowed (European Commission, 2024). The large variety of farm characteristics highlights the importance of farm specific adaptations for improved laying hen welfare (Bestman & Wagenaar, 2003; Blokhuis & van der Haar, 1989).

Conclusion

This study demonstrates that straw enrichment is an effective intervention for reducing FD and so improving welfare of laying hens. By providing a substrate for foraging, straw enrichment can reduce FD, and likely even FP, promoting better feather condition, feather regrowth and overall health. These findings support the adoption of enrichment strategies in poultry management at non-cage systems to enhance animal welfare. Though, farm-specific needs should be considered and effective enriching strategics should be assessed to optimize management. The current study highlights that even simple measures, such as providing straw, can lead to noticeable improvements in feather condition on short terms. Further research is needed to explore long-term effects and optimize enrichment practices for more diverse farm conditions that can influence the outcome of the used assessments. All farms should be frequently informed, updated, and advised on feather damage and FP preventing measurements, to prevent this common problem from occurring in the future, especially now that cages are increasingly banned worldwide. Animal welfare should after always be prioritized, as it is important for all; humans and animals.

Acknowledgements

After months of practical research on farms, writing, meetings and calls, this research-project has come to an end. This project was the final big project to complete my master veterinary medicine of companion animals at Utrecht University and I really enjoyed doing it at the department of Animals in Science and Society. I would firstly want to thank Saskia Kliphuis for her passion for the subject, and for her patience and feedback; you made this research way more fun to do and helped me through it, step by step. I also want to thank Bas Rodenburg, the first corrector of this research, for his feedback, advice, and time. Furthermore, I would like to thank Herenboeren and all farmers that offered their time and chickens for this research. I would like to thank my partner for her help and patience during the hours I worked on this project; you made it bearable! And last but not least I would like to thank Jeroen Imholz, for being the best study partner; without you my life during the master degree would not have been as much fun at all; what a blast it was to do most things together with you!

References

1. Ambrosen, T., & Petersen, V. E. (1997). The influence of protein level in the diet on cannibalism and quality of plumage of layers. *Poultry Science*, *76*(4), 559-563.

2. 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(02), 109–128. https://doi.org/10.1079/wps19910013

3. Bessei, A. W., & Kjaer, J. B. (2015, February). Feather pecking in layers–state of research and implications. In Australian Poultry Science Symposium (Vol. 26, No. 9, pp. 214-221).

4. Bestman, M., Koene, P., & Wagenaar, J. P. (2009). Influence of farm factors on the occurrence of feather pecking in organic reared hens and their predictability for feather pecking in the laying period. Applied Animal Behaviour Science, 121(2), 120-125.

5. Bestman, M. W. P., & Wagenaar, J. P. (2003). Farm level factors associated with feather pecking in organic laying hens. *Livestock Production Science*, *80*(1-2), 133-140.

6. Blokhuis, H. V., & Van Der Haar, J. W. (1989). Effects of floor type during rearing and of beak trimming on ground pecking and feather pecking in laying hens. Applied Animal Behaviour Science, 22(3-4), 359-369

7. Bilcik, B., & Keeling, L. J. (1999). Changes in feather condition in relation to feather pecking and aggressive behaviour in laying hens. British Poultry Science, 40(4), 444-451.

8. Bist, R. B., Subedi, S., Yang, X., & Chai, L. (2023). Effective strategies for mitigating feather pecking and cannibalism in cage-free W-36 pullets. Poultry, 2(2), 281-291. https://doi.org/10.3390/poultry2020021

9. Blokhuis, H. J. (1989). The development and causation of feather pecking in the domestic fowl. (Doctoral dissertation, Vakgroep Ethologie, Landbouw Universiteit Wageningen, Wageningen).

10. Blokhuis, H. J., & Arkes, J. G. (1984). Some observations on the development of feather-pecking in poultry. Applied Animal Behaviour Science, 12(1-2), 145-157.

11. Blokhuis, H. J. (1986). Feather-pecking in poultry: its relation with ground-pecking. Applied Animal Behaviour Science, 16(1), 63-67.

12. Blokhuis, H. J., & Van der Haar, J. (1992). Effects of pecking incentives during rearing on feather pecking of laying hens. British Poultry Science, 33(1), 17-24.

13. Blokhuis, H. J., Van Niekerk, T. F., Bessei, W., Elson, A., Guémené, D., Kjaer, J. B., & Van De Weerd, H. A. (2007). The LayWel project: welfare implications of changes in production systems for laying hens. World's Poultry Science Journal, 63(1), 101-114.

14. Blokhuis, H. J., Cepero, R., Colin, P., Elson, A., Fiks van Niekerk, T., Keeling, L., Michel, V., Nicol, C. J., Oester, H., & Tauson, R. (2005). Welfare aspects of various systems of keeping laying hens. EFSA Journal, 197, 1-23.

15. Brambell Committee. (1965). Report of the Technical Committee to Enquire into the Welfare of Animals kept under Intensive Livestock Husbandry Systems. The Brambell Report.

16. Broom, D. M. (2001). Coping, stress, and welfare. In D. M. Broom (Ed.), *Stress and Animal Welfare* (pp. 1-9). Springer.

17. Campe, A., Hoes, C., Koesters, S., Froemke, C., Bougeard, S., Staack, M., Knierim, U. (2018). Analysis of the influences on plumage condition in laying hens: How suitable is a whole body plumage score as an outcome?. *Poultry science*, *97*(2), 358-367.

18. Cheng, H. (2006). Morphopathological changes and pain in beak trimmed laying hens. World's Poultry Science Journal, 62(1), 41-52.

19. Cooper, J. J., & Albentosa, M. J. (2003). Behavioural priorities of laying hens. https://www.cabidigitallibrary.org/doi/full/10.5555/20033175462

20. Cronin, G. M., & Glatz, P. C. (2020). Causes of feather pecking and subsequent welfare issues for the laying hen: a review. Animal Production Science, 61(10), 990-1005.

21. Cronin, G. M., Hopcroft, R. L., Groves, P. J., Hall, E. J. S., Phalen, D. N., & Hemsworth, P. H. (2018). Why did severe feather pecking and cannibalism outbreaks occur? An unintended case study while investigating the effects of forage and stress on pullets during rearing. *Poultry Science*, *97*(5), 1484-1502.

22. Defra (Department for Environment, Food and Rural Affairs), (2005). A guide to the practical management of feather pecking & cannibalism in free range laying hens (PB 10596). https://www.defra.gov.uk

23. Demartoto, A., Soemanto, R. B., & Zunariyah, S. (2017). Zoo agent's measure in applying the five freedoms principles for animal welfare. Veterinary World, 10(9), 1026–1034. https://doi.org/10.14202/vetworld.2017.1026-1034

24. Desbruslais, A., Wealleans, A., Gonzalez-Sanchez, D., & di Benedetto, M. (2021). Dietary fibre in laying hens: a review of effects on performance, gut health and feather pecking. *World's Poultry Science Journal*, *77*(4), 797-823.

25. Drake, K. A., Donnelly, C. A., & Dawkins, M. S. (2010). Influence of rearing and lay risk factors on propensity for feather damage in laying hens. British Poultry Science, 51(6), 725-733.

26. Duncan, I. J. (2019). Animal welfare: a brief history. In Animal welfare: From science to law (pp. 13-19). https://www.fondation-droit-animal.org/proceedings-aw/animal-welfare-a-brief-history/

27. European Commission. (2024). Laying hens. Retrieved from: https://food.ec.europa.eu/animals/animal-welfare/animal-welfare-practice/animal-welfare-farm/laying-hens_en

28. Eurogroup for Animals. (2023). Better lives for laying hens. Retrieved from https://www.eurogroupforanimals.org

29. European Parliament, Council of the European Union. (2010). Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals used for scientific purposes. Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX%3A32010L0063%3AEN%3AHTML

30. European Parliament (2020). *'End the Cage Age' report*. Retrieved from https://www.europarl.europa.eu/cmsdata/231961/'End%20the%20Cage%20Age'%20report,%20October%202020.pdf

31. Eurostat. (2022). Poultry production. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Poultry_statistics#Poultry_production

32. Fogle, B. (1999). The changing roles of animals in Western society: Influences upon and from the veterinary profession. Anthrozoös, 12(4), 234–239. https://doi.org/10.2752/089279399787000084

33. Fossum, O., Jansson, D. S., Etterlin, P. E., et al. (2009). Causes of mortality in laying hens in different housing systems in 2001 to 2004. Acta Veterinaria Scandinavica, 51(3). https://doi.org/10.1186/1751-0147-51-3

34. Fraser, D., Weary, D. M., Pajor, E. A., & Milligan, B. N. (1997). A scientific conception of animal welfare that reflects ethical concerns. *Animal Welfare*, 6(3), 187-205.

35. Gentle, M. J., & Hunter, L. N. (1991). Physiological and behavioural responses associated with feather removal in Gallus gallus var domesticus. Research in Veterinary Science, 50(1), 95-101.

36. Gilani, A. M., Knowles, T. G., & Nicol, C. J. (2013). The effect of rearing environment on feather pecking in young and adult laying hens. Applied Animal Behaviour Science, 148(1-2), 54-63.

37. Grams, V., Bögelein, S., Grashorn, M. A., et al. (2015). Quantitative genetic analysis of traits related to fear and feather pecking in laying hens. Behaviour Genetics, 45, 228–235. https://doi.org/10.1007/s10519-014-9695-1

38. Gunnarsson, S., Keeling, L. J., & Svedberg, J. (1999). Effect of rearing factors on the prevalence of mislaid eggs, cloacal cannibalism, and feather pecking in commercial flocks of loose housed laying hens. British Poultry Science, 40, 12–18. https://doi.org/10.1080/00071669987773

39. Guyonnet. (2022). How laying hens are kept around the world. Retrieved from https://www.wattagnet.com/egg/egg-production/article/15535764/how-laying-hens-are-kept-around-the-world

40. Harrison, R. (2013). Animal machines. CABI.

41. Hartcher, K. M., & Jones, B. (2017). The welfare of layer hens in cage and cage-free housing systems. World's Poultry Science Journal, 73(4), 767-782.

42. Hartcher, K. M., Tran, K. T. N., Wilkinson, S. J., Hemsworth, P. H., Thomson, P. C., & Cronin, G. M. (2015). The effects of environmental enrichment and beak-trimming during the rearing period on subsequent feather damage due to feather-pecking in laying hens. Poultry Science, 94(5), 852-859.

43. Hartcher, K. M., Wilkinson, S. J., Hemsworth, P. H., & Cronin, G. M. (2016). Severe feather-pecking in non-cage laying hens and some associated and predisposing factors: a review. World's Poultry Science Journal, 72(1), 103-114.

44. He, S., Lin, J., Jin, Q., Ma, X., Liu, Z., Chen, H., Ma, J., Zhang, H., Descovich, K., Phillips, C. J. C., Hartcher, K., & Wu, Z. (2022). The relationship between animal welfare and farm profitability in cage and free-range housing systems for laying hens in China. Animals, 12(16), 2090. https://doi.org/10.3390/ani12162090

45. Hedlund, L., & Jensen, P. (2022). Effects of stress during commercial hatching on growth, egg production, and feather pecking in laying hens. PLoS One, 17(1), e0262307.

46. Heeger, R., & Brom, F. W. (2001). Intrinsic value and direct duties: From animal ethics towards environmental ethics?. Journal of Agricultural and Environmental Ethics, 14, 241–252. https://doi.org/10.1023/A:1011319921159

47. Hemsworth, P. H., & Edwards, L. E. (2020). Natural behaviours, their drivers and their implications for laying hen welfare. Animal Production Science, 61(10), 915-930.).

48. House of commons library. (2023). The use of cages for farmed animals. Retrieved from https://commonslibrary.parliament.uk

49. Van Horne, P. L. M., & Achterbosch, T. J. (2008). Animal welfare in poultry production systems: impact of EU standards on world trade. World's Poultry Science Journal, 64(1), 40-52.

50. 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*(4), 861-873.

51. Huber-Eicher, B., & Audigé, L. (1999). Analysis of risk factors for the occurrence of feather pecking in laying hen growers. British Poultry Science, 40(5), 599-604.

52. Huber-Eicher, B. (1999). A survey of layer-type pullet rearing in Switzerland. World's Poultry Science Journal, 55, 83-91.

53. Huber-Eicher, B., & Sebö, F. (2001). The prevalence of feather pecking and development in commercial flocks of laying hens. Applied Animal Behaviour Science, 74(3), 223-231.

54. Huber-Eicher, B., & Wechsler, B. (1997). Feather pecking in domestic chicks: its relation to dustbathing and foraging. Animal Behaviour, 54(4), 757-768.

55. Janczak, A. M., & Riber, A. B. (2015). Review of rearing-related factors affecting the welfare of laying hens. Poultry Science, 94(7), 1454-1469.

56. Jensen, P., Keeling, L., Schütz, K., Andersson, L., Mormède, P., Brändström, H., ... & Kindmark, A. (2005). Feather pecking in chickens is genetically related to behavioural and developmental traits. Physiology & Behavior, 86(1-2), 52-60.

57. de Jong, I. C., & Blokhuis, H. J. (2014). The welfare of laying hens. https://edepot.wur.nl/465421#:~:text=Foraging%20behaviour%20was%20also%20observedto%20the%20furnished%20cage%20system

58. Johnsen, P. F., Vestergaard, K. S., & Norgaard Nielsen, G. (1998). Influence of early rearing conditions on the development of feather pecking and cannibalism in domestic fowl. Applied Animal Behaviour Science, 60, 25-41.

59. Jung, L., & Knierim, U. (2019). Differences between feather pecking and non-feather pecking laying hen flocks regarding their compliance with recommendations for the prevention of feather pecking–a matched concurrent case-control design. Applied animal behaviour science, 219, 104839.

60. Katiyar, A. K., Vegad, J. L., & Awadhiya, R. P. (1992). Pathology of inflammatory-reparative response in punched wounds of the chicken skin. *Avian Pathology*, *21*(3), 471-480.

61. Kjaer, J. B., Glawatz, H., Scholz, B., Rettenbacher, S., & Tauson, R. (2011). Reducing stress during welfare inspection: validation of a non-intrusive version of the LayWel plumage scoring system for laying hens. *British poultry science*, *52*(2), 149-154.

62. Knierim, U., Staack, M., Gruber, B., Keppler, C., Zaludik, K., & Niebuhr, K. (2008). Risk factors for feather pecking in organic laying hens–starting points for prevention in the housing environment.

63. Lambton, S. (2008). The factors affecting the development of injurious pecking in laying hens (Doctoral dissertation, University of Bristol).

64. Lambton, S. L., Nicol, C. J., Friel, M., & Main, D. C. J. (2010). The impact of environmental design on laying hen welfare: Welfare outcomes in standard and enriched cages. Animal Welfare, 19(3), 421-431.

65. Lambton, S. L., Nicol, C. J., Friel, M., Main, D. C., McKinstry, J. L., Sherwin, C. M., Weeks, C. A. (2013). A bespoke management package can reduce levels of injurious pecking in loose-housed laying hen flocks. Veterinary Record, 172(16), 423-423.

66. Lay Jr, D. C., Fulton, R. M., Hester, P. Y., Karcher, D. M., Kjaer, J. B., Mench, J. A., Porter, R. E. (2011). Hen welfare in different housing systems. Poultry science, 90(1), 278-294.

67. Leeson, S., & Walsh, T. (2004). Feathering in commercial poultry II. Factors influencing feather growth and feather loss. *World's Poultry Science Journal*, *60*(1), 52-63.

68. Majewski, E., Potori, N., Sulewski, P., Wąs, A., Mórawska, M., Gębska, M., Erdős, A. (2024). End of the Cage Age? A study on the impacts of the transition from cages on the EU laying hen sector. Agriculture, 14(1), 111.

69. Martin, G., Sambraus, H. H., & Steiger, A. (2005). Welfare of laying hens in Europe. *Reports, analyses and conclusions. Series: Tierhaltung [Animal Husbandry]*, *28*.

70. McAdie, T. M., & Keeling, L. J. (2000). Effect of manipulating feathers of laying hens on the incidence of feather pecking and cannibalism. Applied Animal Behaviour Science, 68, 215-229.

71. Mumma, J. O., Thaxton, J. P., Vizzier-Thaxton, Y., & Dodson, W. L. (2006). Physiological stress in laying hens. Poultry Science, 85(4), 761-769. https://www-sciencedirect-com.proxy.library.uu.nl/science/article/pii/S0032579119421809

72. Nicol, C. (2018). Feather pecking and cannibalism: Can we really stop beak trimming? In Advances in Poultry Welfare (pp. 175-197). Woodhead Publishing. https://doi.org/10.1016/B978-0-08-100915-4.00009-9

73. Nicol, C. J., Bouwsema, J., Caplen, G., Davies, A. C., Hockenhull, J., Lambton, S. L., ... & Weeks, C. A. (2017). Farmed bird welfare science review (p. 321). Melbourne: Department of Economic Development, Jobs, Transport and Resources.

74. Nicol, C. J., Gregory, N. G., Knowles, T. G., Parkman, I. D., & Wilkins, L. J. (1999). Differential effects of increased stocking density, mediated by increased flock size, on feather pecking and aggression in laying hens. *Applied Animal Behaviour Science*, *65*(2), 137-152.

75. Nicol, C. J., Lindberg, A. C., Phillips, A. J., Pope, S. J., Green, L. E., & Wilson, A. D. (1999). Influence of prior exposure to wood shavings on feather pecking, dustbathing and foraging in adult laying hens. Applied Animal Behaviour Science, 63(2), 137-150. https://doi.org/10.1016/S0168-1591(99)00011-3

76. 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*(3-4), 345-352.

77. Ohl, F., & Van der Staay, F. J. (2012). Animal welfare: At the interface between science and society. *The Veterinary Journal*, *192*(1), 13-19.

78. Olsson, I. A. S., & Keeling, L. J. (2002). The Push-Door for Measuring Motivation in Hens: Laying Hens are Motivated to Perch at Night. Animal Welfare, 11(1), 11–19. doi:10.1017/S0962728600024283

79. Petek, M., & McKinstry, J. L. (2010). Reducing the prevalence and severity of injurious pecking in laying hens without beak trimming. Uludağ Üniversitesi Veteriner Fakültesi Dergisi, 29(1), 61-68.

80. Poultryworld. (2021). European Parliament votes to ban the use of cages by 2027. https://www.poultryworld.net/poultry/european-parliament-votes-to-ban-the-use-of-cages-by-2027/

81. Quartarone, V., Rocca, G. D., & Passantino, A. (2012). Beak trimming and other pain's sources in laying hens and broilers: Welfare problems and medico-legal aspects.

82. Ramadan, S. G. A., & Von Borell, E. (2008). Role of loose feathers on the development of feather pecking in laying hens. *British Poultry Science*, *49*(3), 250-256.

83. Rijksoverheid. (2023, December 11). Convenant dierwaardige veehouderij. Retrieved from https://www.rijksoverheid.nl/documenten/convenanten/2022/11/04/convenant-dierwaardige-veehouderij

84. Ritchie, H. (2023). Do better cages or cage-free environments really improve the lives of hens? Retrieved from https://ourworldindata.org/do-better-cages-or-cage-free-environments-really-improve-the-lives-of-hens

85. Rodenburg, T. B., de Haas, E. N., Nielsen, B. L., & Buitenhuis, A. J. (2010). Fearfulness and feather damage in laying hens divergently selected for high and low feather pecking. Applied Animal Behaviour Science, 128(1-4), 91-96. https://doi.org/10.1016/j.applanim.2010.09.017

86. Rodenburg, T. B., van Krimpen, M. M., De Jong, I. C., De Haas, E. N., Kops, M. S., Riedstra, B. J., Nordquist, R. E., Wagenaar, J. P., Bestman, M., & Nicol, C. J. (2013). The prevention and control of feather pecking in laying hens: identifying the underlying principles. World's Poultry Science Journal, 69(2), 361-374. https://doi.org/10.1017/S0043933913000354

87. Rodenburg, T. B., Reu, K. D., & Tuyttens, F. A. M. (2012). Performance, welfare, health, and hygiene of laying hens in non-cage systems in comparison with cage systems. In Alternative systems for poultry: health, welfare, and productivity (pp. 210-224). Wallingford, UK: CABI.

88. Rodenburg, T. B., Tuyttens, F. A., Sonck, B., De Reu, K., Herman, L., & Zoons, J. (2005). Welfare, health, and hygiene of laying hens housed in furnished cages and in alternative housing systems. Journal of Applied Animal Welfare Science, 8(3), 211-226. https://doi.org/10.1207/s15327604jaws0803_5

89. Rushen, J. (2008). Farm animal welfare since the Brambell report.

90. Rudkin, C. (2022). Feather pecking and foraging uncorrelated–the redirection hypothesis revisited. British Poultry Science, 63(3), 265-273.

91. Savory, C. J. (1995). Feather pecking and cannibalism. World's Poultry Science Journal, 51(2), 215-219.

92. 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(1), 38-47.

93. Sayer, K. (2013). Animal Machines: the public response to intensification in Great Britain, c. 1960–c. 1973. Agricultural History, 87(4), 473-501.

94. Schreiter, R., Damme, K., von Borell, E., Vogt, I., Klunker, M., & Freick, M. (2019). Effects of litter and additional enrichment elements on the occurrence of feather pecking in pullets and laying hens–a focused review. *Veterinary medicine and science*, *5*(4), 500-507.

95. Schuck-Paim, C., Negro-Calduch, E., & Alonso, W. J. (2021). Laying hen mortality in different indoor housing systems: a meta-analysis of data from commercial farms in 16 countries. Scientific Reports, 11(1), 3052.

96. Schwarzer, A., Plattner, C., Bergmann, S., Rauch, E., Erhard, M., Reese, S., & Louton, H. (2021). Feather pecking in non-beak-trimmed and beak-trimmed laying hens on commercial farms with aviaries. Animals, 11(11), 3085.

97. Schwarzer, A., Rauch, E., Erhard, M., Reese, S., Schmidt, P., Bergmann, S., Louton, H. (2022). Individual plumage and integument scoring of laying hens on commercial farms: correlation with severe feather pecking and prognosis by visual scoring on flock level. *Poultry Science*, *101*(10), 102093.

98. Star, L., Arsiwalla, T., Molist, F., Leushuis, R., Dalim, M., & Paul, A. (2020). Gradual provision of live black soldier fly (Hermetia illucens) larvae to older laying hens: effect on production performance, egg quality, feather condition, and behavior. Animals, 10, 7-18.

99. van Staaveren, N., Ellis, J., Baes, C. F., & Harlander-Matauschek, A. (2021). A meta-analysis on the effect of environmental enrichment on feather pecking and feather damage in laying hens. Poultry Science, 100(2), 397-411.

100. Son, J., Lee, W.-D., Kim, H.-J., Kang, B.-S., & Kang, H.-K. (2022). Effect of providing environmental enrichment into aviary house on the welfare of laying hens. Animals, 12(9), 1165. https://doi.org/10.3390/ani12091165

101. Sun, Y., Ellen, E. D., van der Poel, J. J., Parmentier, H. K., & Bijma, P. (2014). Modelling of feather pecking behavior in beak-trimmed and non-beak-trimmed crossbred laying hens: Variance component and trait-based approach. Poultry Science, 93(4), 773-783. https://doi.org/10.3382/ps.2013-03367

102. Tauson, R., & Svensson, S. A. (1981). Influence of plumage conditions on the hen's feed requirement. British Poultry Science, 22(3), 241-247. https://doi.org/10.1080/00071688108447880

103. Tauson, R., Kjaer, J., Maria, G. A., Cepero, R., & Holm, K. E. (2004). The creation of a common scoring system for the integument and health of laying hens. Applied Scoring of Integument and Health in Laying Hens. Retrieved from http://www.laywel.eu (accessed on 17 August 2017).

104. Thaxton, J. P. (2004). Stress and the welfare of laying hens. In Welfare of the laying hen (pp. 81-95). Wallingford, UK: CABI Publishing. https://doi.org/10.1079/9780851998138.0081

105. Webster, J. (2016). Animal welfare: Freedoms, dominions, and "A life worth living". Animals, 6(6), 35. https://doi.org/10.3390/ani6060035

106. Welfare Quality Network. (2009). *Welfare Quality® Assessment Protocol for poultry (broilers, laying hens)*. Retrieved from https://www.welfarequalitynetwork.net/media/1019/poultry_protocol.pdf

107. Wet dieren artikel 2.8. (2024). Retrieved from https://wetten.overheid.nl/BWBR0030250/2024-01-01

108. Wet dieren artikel 1.2. (2024). Retrieved from https://wetten.overheid.nl/BWBR0030250/2024-01-01

109. Wilkins, L. J., Brown, S. N., Zimmerman, P. H., Leeb, T., & Nicol, C. J. (2004). The LayWel project: welfare implications of changes in production systems for laying hens. *World's Poultry Science Journal*, 60(4), 461-474. Https://doi.org/10.1079/WPS200421

110. Windhorst, H.-W. (2017). Housing systems in laying hen husbandry. Zootecnica International. Retrieved from https://zootecnicainternational.com/featured/housing-systems-laying-hen-husbandry

111. Wood-Gush, D.G.M. & Rowland, C.G. (1973). Allopreening in the domestic fowl. Revue Comportement Animal, 7: 83–91.

112. Wu, P., Jiang, T.-X., Lei, M., Chen, C.-K., Hsieh, Li, S.-M., Widelitz, R. B., & Chuong, C.-M. (2021). Cyclic growth of dermal papilla and regeneration of follicular mesenchymal components during feather cycling. Development, 148(18), dev198671. https://doi.org/10.1242/dev.198671

113. Yuhuan, W., & Fu, Q. (2019). Analysis on production efficiency of laying hens in China, based on the survey data of five provinces. Journal of Agricultural Science, 11(8), 280.

114. Zeltner, E., Klein, T., & Huber-Eicher, B. (2000). Is there social transmission of feather pecking in groups of laying hen chicks?. Animal Behaviour, 60(2), 211-216.

115. Zepp, M., Louton, H., Erhard, M., Schmidt, P., Helmer, F., & Schwarzer, A. (2018). The influence of stocking density and enrichment on the occurrence of feather pecking and aggressive pecking behavior in laying hen chicks. *Journal of Veterinary Behavior*, *24*, 9-18.

Appendix

Abbreviation list

FD: Feather Damage

FP: Feather Pecking

FS: Feather Score

HPAI: Highly Pathogenic Avian Influenza

PFS: Pin Feather Score

TPFS: Total Pin Feather Score

TS: Total Score

WS: Wound Score

Tables

TABLE A1: Data of farm visits

	Visit 1	Visit 2 *(1st assessment after intervention)*	Visit 3 *(2nd assessment after intervention)*
Group A - Farm 1	Jan 25th	Feb 12th	Feb 26th
Group B - Farm 2	Jan 27th	Feb 14th	Feb 28th
Group C - Farm 3	Jan 29th	Feb 16th	Mar 1st
Group D - Farm 4	Jan 31st	Feb 18th	Mar 4th

TABLE A2: example of scoring table, as used for Feather Score (FS = BP1-BP6), Wound Score (WS = BP7-BP8) and Total Score (TS = BP1-BP8). BP = body part

Group	Time point	Chicken	Chicken-Cumulative	BP1 Head and neck	BP2 Wings	BP3 Back	BP4 Tail	BP5 Breast	BP6 Abdomen	**FS**	BP7 Comb	BP8 Vent	**WS**	**TS**
A	T1	1/50	001	3	2	4	1	2	3	**15**	4	2	**6**	**21**
A	T1	2/50	002	4	3	4	2	3	2	**18**	3	3	**6**	**24**
B	T1	1/50	051	2	3	4	2	1	3	**15**	4	2	**6**	**21**
..	…	…	…	…	…	…	…	…	…	**…**	…	…	**…**	**…**
B	T2	4/50	225	3	4	4	3	4	3	**21**	3	3	**6**	**28**
B	T2	5/50	226	3	1	4	3	2	1	**14**	4	3	**7**	**21**
…	…	…	…	…	…	…	…	…	…	**…**	…	…		**…**
D	T	50/50	600	4	4	4	4	4	4	**24**	4	4	**8**	**32**

TABLE A3: Shapiro-Wilk's test results and transformations on TS. *Significant values are indicated by a **

Transformation	W	P-value
Original data	0.85306	<0,05*
Log	0.82823	<0,05*
Square root	0.8	<0,05*
Box-cox	0.85	<0,05*

TS

Table A4: descriptive statistics; means, standard deviation and variation in all groups at different time points for TS. Lowest possible min score = 8, highest possible max score = 32.

Group	Time Point	n	Mean	Std Dev	Min	25%	50%	75%	Max
A	T1	50	31.0	1.03	28	30	31	32	32
A	T2	50	30.7	1.01	28	30	31	31	32
A	T3	50	31.0	1.10	28	30	31	32	32
B	T1	50	24.4	2.60	19	23	24	26	30
B	T2	50	25.8	3.32	16	24	26	28	32
B	T3	50	26.2	2.50	21	25	26.5	28	30
C	T1	50	25.0	3.08	19	23	25	27	31
C	T2	50	27.2	3.34	18	25	28	30	31
C	T3	50	28.9	2.08	23	28	29	30	32
D	T1	50	31.5	0.65	30	31	32	32	32
D	T2	50	31.7	0.52	30	31	32	32	32
D	T3	50	31.8	0.37	31	32	32	32	32
Tot	T1	200	28.0	3.88	19	25	29	31	32
Tot	T2	200	28.8	3.42	16	27	30	31	32
Tot	T3	200	29.5	2.79	21	28	30	32	32

FS

TABLE A5: descriptive statistics; means, standard deviation and variation in all groups at different time points for FS. Lowest possible min score = 6, highest possible max score = 24.

Group	Time Point	n	Mean	Std Dev	Min	25%	50%	75%	Max
A	T1	50	23.0	0.99	20	23	23	24	24
A	T2	50	23.1	1.02	21	22	23.5	24	24
A	T3	50	23.2	1.08	20	22.2	24	24	24
B	T1	50	17.7	2.43	13	16	17.5	19	24
B	T2	50	18.6	3.04	11	17	18	20	24
B	T3	50	18.6	2.33	13	17	19	20.8	22
C	T1	50	19.0	2.63	13	18	19	21	23
C	T2	50	20.4	2.78	13	19	21	23	24
C	T3	50	21.4	2.08	15	21	22	23	24
D	T1	50	23.7	0.55	22	23	24	24	24
D	T2	50	23.8	0.45	22	24	24	24	24
D	T3	50	23.9	0.24	23	24	24	24	24
Tot	T1	50	20.8	3.18	13	18	22	24	24
Tot	T2	50	21.5	2.99	11	19	23	24	24
Tot	T3	50	21.8	2.62	13	20	23	24	24

WS

Table A6: descriptive statistics; means, standard deviation and variation in all groups at different time points for WS. Lowest possible min score = 2, highest possible max score = 8.

Group	Time Point	n	Mean	Std Dev	Min	25%	50%	75%	Max
A	T1	50	7.92	0.27	7	8	8	8	8
A	T2	50	7.6	0.54	6	7	8	8	8
A	T3	50	7.82	0.39	7	8	8	8	8
B	T1	50	6.76	0.69	5	6	7	7	8
B	T2	50	7.2	0.81	5	7	7	8	8
B	T3	50	7.52	0.81	4	7	8	8	8
C	T1	50	6.08	1.01	4	5	6	7	8
C	T2	50	6.76	1.02	3	6.25	7	7	8
C	T3	50	7.48	0.71	5	7	8	8	8
D	T1	50	7.84	0.42	6	8	8	8	8
D	T2	50	7.86	0.35	7	8	8	8	8
D	T3	50	7.9	0.30	7	8	8	8	8
Tot	T1	200	7.15	1.01	4	6.75	7	8	8
Tot	T2	200	7.355	0.83	3	7	8	8	8
Tot	T3	200	7.68	0.62	4	7	8	8	8

PFS to TPFS

TABLE A7: Formation of the TPFS. PFS for each body part were added to a total PFS. If all body parts scored an A, TPFS was 0. If a hen had received at least one B but no C in one of the body parts, TPFS was 1. If at least one C was present in one of the body parts, TPFS was 2.

Group	Time point T	Kip	BP1	BP2	BP3	BP4	BP5	BP6	TPFS
A	T1	001	A	A	A	A	A	A	0
A	T1	002	A	B	A	B	A	C	2
B	T1	051	B	A	A	A	A	A	1
..									
A	T2	201	A	A	A	B	A	A	1
..									
D	T3	800	A	C	A	A	A	C	2

TPFS: Distribution of chickens per group

TABLE A8: Distribution of chickens' TPFS (0-1-2) for each group at each time point (T)

Group	Hens assessed	T1	T2	T3
A	50	0: 48 (96%) 1: 2 (4%) 2: 0 (0%)	0: 48 (96%) 1: 2 (4%) 2: 0 (0%)	0: 46 (92%) 1: 4 (8%) 2: 0 (0%)
B	50	0: 41 (82%) 1: 8 (16%) 2: 1 (2%)	0: 34 (68%) 1: 14 (28%) 2: 2 (4%)	0: 16 (32%) 1: 25 (50%) 2: 9 (18%)
C	50	0: 41 (82%) 1: 7 (14%) 2: 2 (4%)	0: 38 (76%) 1: 10 (20%) 2: 2 (4%)	0: 31 (62%) 1: 14 (28%) 2: 5 (10%)
D	50	0: 50 (100%) 1: 0 (0%) 2: 0 (0%)	0: 50 (100%) 1: 0 (0%) 2: 0 (0%)	0: 50 (100%) 1: 0 (0%) 2: 0 (0%)
Tot	200	0: 180 (90%) 1: 17 (8,5%) 2: 3 (1,5%)	0: 170 (85%) 1: 26 (13%) 2: 4 (2%)	0: 143 (71.5%) 1: 43 (21.5%) 2: 14 (7%)

TABLE A9: Studies describing their findings on body parts that are predominantly affected by feather pecking

Research	Body parts predominantly affected by feather pecking
Bilcik & Keeling, 1999	- Abdomen - Rump - Back - Legs - Neck - Underneck - Many aggressive pecks are towards head and comb (cronin zegt di took)
Zepp et al., 2018	- Back - Side (incl. wings) - Neck

Nørgaard-Nielsen et al., 1993	- Breast - Back
Ramadan & von Borell, 2008	- Wings - Rump - Tail - Back
Martin et al., 2005	- Neck - Back
Schwarzer et al., 2022	- Neck - Back
McAdie & Keeling, 2000	- Rump - Tail - Abdomen
Wood-Gush & Rowland, 1973	- Rump - Tail - Back
Savory & Mann, 1997	- Mostly on the back - Thigh
Cronin et al., 2018	- Tail - Rump

Illustrative photos

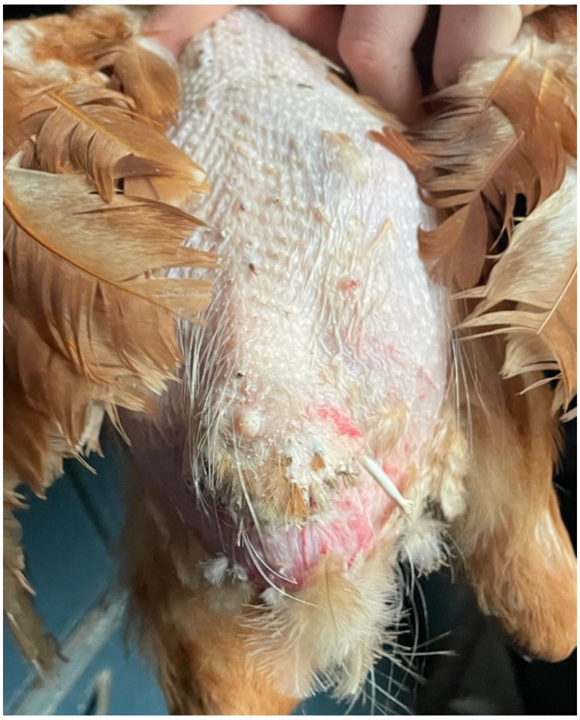
Puddles and muddy areas were covered before enrichment was applied. Straw was used to enrich the chicken run and was refreshed every two weeks.


Assessment was started once chickens got used to the presence of the researchers.


(L) Hens were is assessed carefully, and all body parts were inspected and (R) a chicken run enriched with straw which chickens have spread throughout and are showing foraging behaviour

An example of a WS 1 out of 4 on the back of a laying hen

Pin feather scores of A (left) and C (right). It should be kept in mind that a fully feathered body part also has a PFS of ‘A’ (no growing pin feathers), but a higher FS than a bald body part.



Farm characteristics were clearly different.

Upper left, farm A, right B. Below left farm C, right farm D**.**

"The manner in which we treat chickens, serves as a testament to our collective conscience, reflecting the deeper values and ethical standards of our society. They provide us food; let us provide them love and treat them the best we can."

-Koen Riep, 2024-