An Investigation of Feather Damage in Canadian Laying Hens

by

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A Thesis
presented to
The University of Guelph

In partial fulfillment of requirements
for the degree of
Master of Science
in
Population Medicine

Guelph, Ontario, Canada

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ABSTRACT

AN INVESTIGATION OF FEATHER DAMAGE IN CANADIAN LAYING HENS

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Feather damage (FD) due to feather pecking behaviour is a significant welfare problem in laying hens housed in modern production systems. The FD prevalence and factors associated with FD in Canadian laying hen flocks housed in alternative systems is described in this thesis. A scoring system for on-farm FD assessment and a questionnaire focused on housing and management practices were developed. The analysis was based on FD scores and cross-sectional survey data collected from egg farms across Canada from October to December 2017. Prevalence of FD was found to be 21.9% (95% CI: 10.4-33.4%) in furnished cage systems, and 25.9% (95% CI: 15.6-36.2%) in non-cage systems. Findings suggest that factors most associated with FD include increased age, lack of foraging opportunity, brown feather colour, abnormal lighting cycle from midnight feeding, and poor air quality due to infrequent manure removal. Further investigation of these factors through longitudinal studies and intervention strategy evaluation is warranted.
ACKNOWLEDGEMENTS

First and foremost, I would like to thank my two co-advisors: Dr. Olaf Berke and Dr. Alexandra Harlander. Olaf, a big thank you for introducing me to this project and giving me the option to switch gears from my original proposed work. This project allowed me to explore a new research field and expand my knowledge of the agricultural world. Thank you for your statistical and conceptual expertise, as well as all of your support, guidance, and encouragement in making my own decisions and thinking critically about data. Alexandra, thank you for allowing me to join this project and for your valuable industry expertise. An even bigger thank you for your endless positivity, encouragement, and praise for all that has been accomplished through this work, including my personal accomplishments. Your hospitality and effort in fostering a happy team environment was also greatly appreciated.

Nienke, thank you so much for being such a great teammate throughout this project. I am incredibly grateful for all of your help and experience with study development, coordination, analysis, writing guidance and for being a sounding board for thoughts and feelings. My thanks also go out to the students of the Harlander lab for your friendship and positivity.

I would like to extend thanks to my committee member, Dr. Christine Baes, and project consultant, Dr. Tina Widowski. Your industry expertise and advice throughout the development of this project was invaluable. I am also grateful for your time and effort in reviewing my thesis. Overall, I could not have asked for better people to guide me through this big step in my academic career, you all have made this a wonderful learning opportunity and fulfilling experience.

A resounding thanks to my friends and family who have supported and encouraged me throughout my graduate program. Mom, Dad, Marissa, and Zias, thank you for cheering me on and being there to lend a hand. Special thanks go to my mom for always being there to listen, help sort out problems, and comfort me in times of stress. You have always been my greatest champion, and I have had the strength to accomplish many things because of you.

This project would not have been possible without the funding support from the Egg Farmers of Canada (EFC), the Ontario Veterinary College (OVC), and Mitacs, or the questionnaire provided by Dr. Christine Nicol from the Royal Veterinary College, University of London.
STATEMENT OF WORK DONE

Study objectives were developed with the assistance and expertise of Drs. Olaf Berke, Alexandra Harlander, Nienke van Staaveren, Christine Baes, and Tina Widowski.

The feather damage scoring system was tested and developed by Caitlin Decina and Dr. van Staaveren. The questionnaire used was supplied by Dr. Christine Nicol from the University of London, UK and modified for Canada by Caitlin Decina and Dr. van Staaveren. Caitlin Decina constructed the online version of the questionnaire. Both the scoring system and questionnaire were reviewed and edited by Drs. Berke, Harlander, Baes, and Widowski.

Data was collected by Caitlin Decina and Dr. van Staaveren, with questionnaire distribution assistance from the Egg Farmers of Canada and provincial egg boards. Data was analyzed by Caitlin Decina and Dr. van Staaveren with input and guidance from Dr. Berke.

The literature review and all research chapters were written by Caitlin Decina, with review and editing performed by Drs. Berke, Harlander, van Staaveren, Baes, and Widowski. Caitlin Decina was also responsible for making all suggested changes following review.

The research described in Chapter 4 was orally presented by Caitlin Decina at the OVC Graduate Student Research Symposium in June 2018, and at the International Society for Applied Ethology (ISAE) conference in Prince Edward Island in August 2018.
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Chapter 1: Literature Review

1.1 Feather Pecking: A Real-World Problem

The issue of laying hen welfare regarding how best to house them while balancing their health, well-being, and production efficiency has been a subject of discussion and study for decades. One of the most prominent welfare issues facing laying hens is that of feather pecking (FP) (Blokhuis 1986; M. Bestman, Koene, and Wagenaar 2009). FP, a form of bird-to-bird pecking, has varying forms of severity. Gentle feather pecking (GFP) causes little or no damage to the recipient and is typically characterized by mild, repeated pecks at the tips of feathers (Savory 1995). Severe feather pecking (SFP) is far more forceful and is the act whereby a hen pulls at (Willimon and Morgan 1953), plucks (Neal 1956), and often eats (McKeegan and Savory 1999; Harlander-Matauschek and Bessei 2005), the feathers of conspecifics, leading to feather damage (FD) and feather loss (Savory 1995). FD can be defined as feathers that are broken, deformed, or deviate from a smooth and intact state. Feather loss is defined as the absence of feathers in small or large areas. It is painful for the individual receiving severe pecks, as evidenced by the agitation and vocalizations that follow when feathers are removed (Gentle and Hunter 1990). When SFP is persistent, completely denuded areas of skin can develop, for which tissue pecking and cannibalism may follow, ultimately leading to mortality due to blood loss (Savory 1995). Both types of FP differ from that of aggressive pecking, where pecks are often aimed at the head and function to assert dominance over a subordinate (Savory 1995). SFP simply referred to as FP hereafter, is instead mainly targeted toward the back/rump, neck, and tail areas (Wood-Gush and Rowland 1973; McAdie and Keeling 2000; Glatz 2001), but can also affect the breast, wings, and vent areas (Wood-Gush and Rowland 1973).
FP is generally accepted to arise from the stress and frustration of living in a barren environment that prevents the expression of natural behaviours such as foraging, nesting, perching, and dustbathing (Blokhuis 1986; Vestergaard, Kruijt, and Hogan 1993; Baxter 1994; Olsson and Keeling 2000). Two main hypotheses have been put forward to explain the underlying aetiology of FP. The first and dominant hypothesis refers to FP as a form of redirected ground-pecking behaviour that arises when birds do not have adequate access to foraging material (Blokhuis 1986). In an experimental study observing the level of pecking behaviour between groups of birds housed in litter pens vs. non-litter pens, Blokhuis (1986) found an increase in pecking at conspecifics after feeding in the non-litter groups, but not in the groups housed with litter. Due to the absence of litter in the non-litter groups, feathers of other birds became an incentive for pecking. The second hypothesis was put forward by Vestergaard et al. (1993), alternatively proposing that FP is more associated with dustbathing. Their experimental study with junglefowl showed that pecking towards conspecifics often occurred within dustbathing behavioural sequences, and the birds housed in barren environments sometimes used feathers as dust substrate (Vestergaard, Kruijt, and Hogan 1993).

Interestingly, research was done by Dixon et al. (2008) using fixed action pattern morphology to discern the motivation behind FP, where they determined that severe feather pecks have similar morphology to foraging pecks and were distinct from all other types of pecks, including pecks at dustbaths. This finding led them to conclude that FP motivation does lie in thwarted foraging opportunities rather than dustbathing. It is important to note, however, that these two hypotheses are not mutually exclusive and both involve the absence of litter as a precursor to FP. It is possible that both foraging and dustbathing behaviours play a role in the development of FP.
The barren conditions that help foster this behaviour are largely found in conventional cage housing, otherwise referred to as battery cages, that have allowed for the intensive farming of laying hens for eggs. Conventional cages are small enclosures of wire mesh with sloping floors for easy egg collection and manure removal (Blokhuis et al. 2007). These cages are approximately 450cm$^2$ per bird, typically housing 5-7 birds each (Canadian Agri-Food Research Council 2003). The separation of birds from manure helps reduce poor air quality and disease burden. However, the cages only provide feeders, drinkers, and claw shortening devices, and severely restrict movement (Blokhuis et al. 2007). Conventional cages thus prevent the performance of natural, highly motivated behaviours such as foraging, dustbathing, perching, nesting, and wing flapping (Baxter 1994).

Alternative housing options that better allow for the expression of hens’ natural behaviours include furnished or enriched cages, single-tier floor (barn) systems, and multi-tier aviary systems – the latter two are also termed free-run systems. Furnished cages provide the same equipment that conventional cages offer with the added benefit of nest boxes, perches, extra height, and a scratch pad area typically with litter material (Blokhuis et al. 2007). These larger cages offer varying group sizes anywhere from 10 to 100+ birds (National Farm Animal Care Council 2017). Single-tier floor systems house birds all on one level, while multi-tier aviary systems feature multiple elevated platforms to provide more space. Both offer a combination of slatted floors and litter, perches, and nest boxes, and can serve as free-range systems if birds have access to the outdoors (National Farm Animal Care Council 2017).
1.2 Prevalence of Feather Pecking

Research on how prevalent FP activity is and how much FD is observed in commercial flocks has indicated that both can reach pronounced levels. FP and integument damage occurs in all types of housing systems (Rodenburg et al. 2008; Sherwin, Richards, and Nicol 2010). However, prevalence within housing systems can vary. Investigation of welfare parameters across all types of housing in the UK by Sherwin et al. (2010) yielded average FD proportions within furnished cage flocks of 24.9%, while in free-run barn systems and free-range systems, proportions of 26.9% and 15.5% were reached, respectively. Other epidemiological studies that assessed FD in exclusively non-cage systems found higher levels, including Gunnarsson et al. (1999) in Sweden who reported a median of 62% of birds in free-run flocks with damage to their back region. In the Netherlands, Bestman and Wagenaar (2003) found moderate or severe FD in 71% of birds in free-range flocks, and de Haas, Bolhuis, Kemp, et al. (2014) found a FD prevalence of 49% at flock level for birds in free-run and free-range systems. When assessing prevalence of FP activity through observation, prevalences of 65% (Gilani, Knowles, and Nicol 2013), and as high as 86% (Lambton et al. 2010), have been found in the UK. It is important to note that variation in these findings can be due to differences in recording methods, the age of birds when results were recorded, breeds used, housing systems involved, and whether or not birds were beak trimmed (Nicol et al. 2013). Nonetheless, these findings indicate that FP and FD have the potential to negatively impact the welfare of a large population of hens.

1.3 Known Associations and Risk Factors of Feather Pecking

Extensive research has determined that there is no single cause of FP behaviour, but rather that it is a multifactorial problem. Risk factors that pertain to internal aspects include genetic
predisposition, fearfulness, social motivation, and developmental stage, while external risk factors include housing conditions (litter substrate, group size, stocking density, air quality) and nutrition, with all factors interacting together (van Krimpen et al. 2005).

1.4 Internal Risk Factors

1.4.1 Genetics & Fearfulness

The genetics and underlying physiology of laying hens play an active part in the propensity to feather peck. The behaviour of FP has been demonstrated to have an element of heritability as evidenced by the creation of low FP lines and high FP lines of birds by Kjaer et al. (2001) when selecting on the number of FP bouts per bird per hour. Significant differences in FP were apparent after just two generations of breeding, where the high FP line performed twice the amount of FP compared to the low FP line, with a seven-fold difference between lines by generation three. Plumage condition was also observed to be of better quality in the low FP line (Kjaer, Sorensen, and Su 2001).

It is believed that the genetic selection for high productivity and housing of birds in modern intensive systems has produced birds that are more fearful (a predisposition to become easily frightened by various stimuli) (Kjaer and Mench 2003). While birds bred from White Leghorn lines are generally considered more fearful (Hughes and Duncan 1972; de Haas, Bolhuis, Kemp, et al. 2014), there are contrasting findings as to whether certain breeds display more fearfulness than others. White Leghorn birds exhibited more fearfulness and FD than Rhode Island Red birds in a study by Uitdehaag et al. (2008). De Haas, Bolhuis, Kemp, et al. (2014) found that Dekalb White birds (descended from White Leghorns) had greater fear of humans than ISA Brown birds (descended from Rhode Island Reds), however the ISA birds became more anxious...
and fearful in response to disruption of litter supply, suggesting that environmental conditions may impact certain breeds differently. Nonetheless, fearfulness has been found to be associated with higher levels of FP in flocks. Birds who are fearful during rearing have been found to develop high FP levels during the laying period (Jones, Blokhuis, and Beuving 1995; Rodenburg et al. 2004). It is suggested that being more fearful leads to birds that are less able to cope with stressors in their environment, and therefore are more susceptible to develop FP as a response (Rodenburg et al. 2013).

1.4.2 Effect of Age & Social Motivation

FP behaviour and FD have been consistently documented to increase and worsen over time, indicating that poor plumage condition has a relationship with age (Bilčík and Keeling 1999; Huber-Eicher and Sebő 2001; Sherwin, Richards, and Nicol 2010; Lambton et al. 2010; Gilani, Knowles, and Nicol 2013). One of the likely mechanisms of this relationship is that FP can be transmitted through social learning, as demonstrated by Zeltner et al. (2000), where groups of chicks introduced to feather-pecking “tutors” showed significantly higher rates of FP compared to control groups. FP is not performed by only a few individuals in a group – many will adopt the behaviour, though some peck at higher rates than others (Wechsler, Huber-Eicher, and Nash 1998). FP may additionally spread throughout a flock when damaged feathers become an attractive stimulus of further pecking, creating a type of feedback loop. This idea was supported by the work of McAdie and Keeling (2000), where the researchers purposely damaged the body areas of birds through feather trimming and removal. These damaged areas received significantly more severe pecks than undamaged areas and spurred an outbreak of cannibalism in half of the experimental groups.
1.5 External Risk Factors

1.5.1 Stocking Density & Group Size

Related to the concept of social transmission of FP are the effects of stocking density and the group size in which birds are housed. Smaller group sizes tend to result in better plumage condition compared to large group sizes, as found for chicks during rearing (de Haas, Bolhuis, de Jong, et al. 2014), caged birds (Hughes and Duncan 1972), and birds kept in floor pens (Bilčík and Keeling 1999) and percheries (Nicol et al. 1999). Similarly with stocking density, feather condition is typically poorer when birds are kept at high density compared to low, as has been found in chicks reared in commercial aviaries (Zepp et al. 2018), chicks reared organically (Bestman, Koene, and Wagenaar 2009), furnished cage-housed hens (Widowski et al. 2014), and perchery-housed hens (Nicol et al. 1999). Stocking density is inter-related with group size, and when both are large, there is greater opportunity for FP to spread socially. There is also simply a larger group of potential victims, even if the number of feather-peckers is few (Rodenburg et al. 2005). Additionally, high stocking density may result in stress and frustration that can promote FP if there is competition for resources or less freedom of movement. From a managerial point of view, FP problems can be hard to control in large flock sizes where feather-peckers are more difficult to identify (Green et al. 2000).

1.5.2 Litter & Foraging Opportunity in Laying Hens

Availability of adequate litter material for the performance of foraging and dustbathing is one of the most prominent environmental factors related to FP in flocks (as reviewed by Rodenburg et al. 2013; Nicol et al. 2013). Epidemiological studies have found associations with absence of litter and increased FP activity or FD in adult hens, such as compacted litter or an absence of loose litter at the end of lay (Green et al. 2000) and restriction to the slatted area during nest box
training (severe FP was 24 times more likely) (Lambton et al. 2010). Furthermore, research conducted in free-range systems has shown that rates of FP and FD decrease with use of the range (Green et al. 2000; Bestman and Wagenaar 2003; Nicol et al. 2003; Lambton et al. 2010)). Having outdoor range access can provide birds with more natural and varied foraging opportunity than indoor housing (Green et al. 2000). It also has the added benefit of lowering stocking density and group size intermittently throughout the day; however, it does not prevent FP (Bestman and Wagenaar 2003).

Promotion of foraging opportunities beyond litter provision and range use have also been investigated and found to be beneficial in the reduction of FP and FD, as it encourages pecking toward other objects in the environment rather than the feathers of flockmates. Recently, Zepp et al. (2018) found that the provision of enrichments such as pecking stones, pecking blocks, and lucerne hay bales significantly reduced the occurrence of FP in groups of chicks housed in commercial rearing conditions, especially paired with a lower stocking density. They also found that these enrichments were somewhat protective in groups stocked at high density, as rates of FP were lower compared to groups at high stocking density with no enrichment (Zepp et al. 2018). Both Jones et al. (2002) and McAdie et al. (2005) have additionally shown evidence for the benefit of string pecking objects, such as white polypropylene baling twine, hung within floor pens. McAdie et al. (2005) found that housing chicks with string objects completely prevented the occurrence of FP when provided continuously from hatch or for only 4 hours per day from hatch, and birds maintained interest in the strings over the entire 57-day observation period. Jones et al. (2002), while unable to precisely determine the efficacy of string as a FP deterrent due to the absence of FP in their study, found that birds also maintained interest in the string, even with a competing stimulus present in the form of birds with purposely damaged feathers.
1.5.3 Rearing Conditions

The impact of rearing conditions, especially in the context of litter availability, has been determined as an important external factor in FP development. Specifically, it has been demonstrated that chicks and pullets reared without suitable litter material develop FP during rearing and show severe FP and poor plumage later in life (Huber-Eicher and Wechsler 1997; Johnsen, Vestergaard, and Nørgaard-Nielsen 1998; Nicol et al. 2001; M. Bestman, Koene, and Wagenaar 2009; de Haas, Bolhuis, Kemp, et al. 2014). In experiments with chicks less than 7 weeks of age, Huber-Eicher and Wechsler (1997) found that when only given access to sand (a dustbathing substrate) from day 1, chicks developed severe FP that caused injuries, while groups housed with straw from day one, did not show high rates of FP or injuries. Furthermore, the sand-only groups showed decreases in FP when provided with straw later in the experiment, suggesting that access to dustbathing material on its own is not sufficient to deter FP development, and that suitable foraging material from hatch is critical (Huber-Eicher and Wechsler 1997). Johnsen et al. (1998), who studied the impact of rearing conditions on FP in adulthood, similarly found that chicks reared on both sand and straw from 0-4 weeks of age had significantly better plumage quality at both 19 and 45 weeks of age compared to those reared on wire or sand only. Epidemiological studies with commercial flocks have found that the first weeks of life are a critical time period for foraging development (Bestman, Koene, and Wagenaar 2009; de Haas, Bolhuis, Kemp, et al. 2014). Not having litter at age 1-4 weeks was a predictor of FD during the laying period in organic flocks according to Bestman et al. (2009), and disruption and limitation of litter supply within the first 5 weeks increased FP and FD in birds kept in indoor floor and aviary systems (de Haas, Bolhuis, Kemp, et al. 2014).
In addition to foraging and dustbathing, birds are highly motivated to perch (Olsson and Keeling 2000) and thwarting of this behaviour by lack of access during rearing can result in frustration and stress that can translate to FP activity. In studies of commercial flocks, Huber-Eicher and Audigé (1999) found that birds on rearing farms reared with no access to elevated perches were 4 times more likely to be affected by FP, while Gunnarsson et al. (1999) found that birds without access to perches beyond 4 weeks of age were 2.17 times more likely to be cannibalised during the production period. Findings such as these underscore the necessity of a fulfilling housing environment and reveal the relationship between environment quality and developmental stage in the likelihood of FP initiation.

1.5.4 Nutrition & Feed Form

Since feathers are highly proteinaceous structures composed of beta-keratin (Scanes 2015), adequate levels of protein and amino acids in the diet is important for biological functioning and feather maintenance (van Krimpen et al. 2005). Nutritional consideration of crude protein and amino acid deficiencies such as cysteine and methionine (major amino acids in feather keratin synthesis) have been shown to result in FP activity, poorer plumage quality, and cannibalism (Neal 1956; Ambrosen and Petersen 1997; Elwinger et al. 2008). This too is the case for deficiencies in mineral content such as sodium (Hughes and Whitehead 1979) and zinc (Sunde 1972). When birds’ dietary requirements are not met, they may feel the need to seek out other sources for foraging, such as feathers, which may be compounded if there is also no access to a suitable foraging substrate. Indeed, birds are known to eat feathers, as indicated by the presence of undigested feathers in fecal droppings and a lack of feathers on the floor (McKeegan and Savory 1999; Savory and Mann 1999). McKeegan and Savory (1999) found that outbreaks of FP and cannibalism occurred in groups of birds where levels of feather eating were highest. Other
studies have similarly shown that high FP birds consume more feathers than low FP birds (Harlander-Matauschek, Baes, and Bessei 2006; Harlander-Matauschek and Häusler 2009). A high rate of FP has been especially associated with low insoluble fibre diets (van Krimpen et al. 2008). Feathers, which are indigestible, have been found to increase feed-passage time in high FP birds, suggesting that they function much like insoluble fibre in the gut (Harlander-Matauschek, Piepho, and Bessei 2006). Studies in which birds have been supplemented with high fibre diets via nonstarch polysaccharides (NSPs) have found reductions in FP, cannibalistic pecking, and FD (van Krimpen et al. 2008; van Krimpen et al. 2009). The first mechanism by which this is thought to be achieved is through increased feeding time to compensate for the comparatively low protein concentration, thus reducing time spent pecking other birds (van Krimpen et al. 2007; van Krimpen et al. 2008). The second mechanism is through increased mean retention time of digesta in the crop and foregut from coarsely ground NSP, thus increasing satiety (van Krimpen et al. 2011).

In addition to feed composition, feed structure in the form of pellets compared to mash, has been found to be an influential factor. In an experiment investigating the effects of foraging material and feed form on FP in adult hens, Aerni et al. (2000) found that FP and corresponding FD was only pronounced in birds housed without straw litter for foraging and fed on pellets, compared to groups housed with mash/no straw, mash/straw, and pellets/straw. The percentage of time spent feeding was significantly greater in the mash-fed groups compared to those fed on pellets and mash was protective against FP in the group without straw litter, suggesting that mashed feed also functioned as a type of foraging material (Aerni, El-Lethey, and Wechsler 2000). Feeding of pelleted food compared to mashed food has also been found to increase FP and result in higher plumage damage in commercial flocks (Lambton et al. 2010).
1.5.5 Air Quality

Lastly, poor air quality as a general irritant and source of stress is a prominent environmental factor that plays into the multifactorial nature of FP behaviour. High levels of ammonia and dust are a particular problem in litter-based systems where manure is composting inside the house (European Food Safety Authority 2005). This has been found in numerous studies when measuring ammonia concentrations in cage systems compared to free-run floor and aviary systems (Michel and Huonnic 2003; Rodenburg et al. 2008; Sherwin, Richards, and Nicol 2010; Zhao et al. 2015). Ammonia is generated from microbial decomposition of uric acid in excreta (Zhao et al. 2015), while dust is contributed by bedding material, feed, dry manure, skin cells, and feathers (Widowski et al. 2013). Dust and gasses can destroy cilia needed to clear debris from the upper respiratory tract (Anderson, Beard, and Hanson 1966), as well as cause lesions throughout the respiratory system (Oyetunde, Thomson, and Carlson 1978). Birds are then predisposed to secondary infection and respiratory diseases caused by airborne microbes when the mucosa is compromised (Anderson, Beard, and Hanson 1964; Oyetunde, Thomson, and Carlson 1978). Ammonia becomes harmful, and birds find it aversive, above concentrations of 20-25 ppm (David et al. 2015). Respiratory stress can then contribute to outbreaks of FP, as found by Drake et al. (2010) where FD increased with higher carbon dioxide and ammonia in early lay. Ammonia at a level of 20-25 ppm is also aversive to barn staff and can compromise their health (Donham et al. 2000), which may lead to reduced care and detection of welfare issues within the flock when workers are reluctant to enter the barn. The potential for poor air quality to result in negative health outcomes and stress, especially in certain housing systems, highlights the need for good farm management in the mitigation of environmental contributions to FD and feather loss in commercial flocks.
1.6 Control Strategies for Feather Pecking and Feather Damage

The primary control method for FP and cannibalism used routinely in the North American poultry industry is that of de-beaking in the form of beak trimming and beak treatment (Dennis, Fahey, and Cheng 2009). Beak trimming is the removal of a portion of both the upper and lower beak with a hot blade that simultaneously cuts and cauterizes, typically performed on chicks at 1-10 days old (Dennis, Fahey, and Cheng 2009; National Farm Animal Care Council 2017). Beak treatment refers to the non-invasive procedure of blunting the beak via infra-red laser on the day of hatching, where the beak tip gradually sloughs off 7-10 days later (Dennis, Fahey, and Cheng 2009; National Farm Animal Care Council 2017). Beak trimming/treatment can have benefit, as studies have shown that birds with intact beaks display greater FP and FD than those without (Lambton et al. 2010; Gilani, Knowles, and Nicol 2013; Hartcher et al. 2015). Flocks do, however, still display FP behaviour and damaged plumage despite beak treatment (Green et al. 2000; van Staaveren et al. 2018). Furthermore, beaks are highly sensory organs (Gentle and Breward 1986) for which beak modification, especially in the form of trimming via hot blade, presents its own welfare issue as it can result in chronic pain (Gentle et al. 1990; Gentle, Hunter, and Waddington 1991). Due to ethical concerns and societal pressures surrounding the practice of de-beaking, some countries such as Sweden, Norway, Finland, and the Netherlands have banned this practice, while others, such as the UK, are still considering its discontinuation in the future once the risk of keeping flocks with intact beaks lessens (Nicol 2018). Other general management control strategies are therefore needed to reduce FP and allow for more flocks to be kept with intact beaks in years to come.
The second most prominent and commonly employed management strategy in the reduction of FP activity is that of keeping birds in low light intensity inside the barn (Green et al. 2000) in order to reduce plumage reflectivity, and therefore, plumage attractiveness (Bright 2007). Additionally, farmers may change the wavelength of light, such as through the use of red light, as it can help reduce the appearance of blood and naked skin (Nicol et al. 2013). Keeping birds at low light intensity in experimental settings has been found to result in less FP and aggressive behaviour than at high intensity as demonstrated by Mohammed et al. (2010) at 5 vs. 50 lux, and by Kjaer and Vestergaard (1999) at 3 vs. 30 lux. Kjaer and Vestergaard (1999) also saw significantly higher mortality in groups housed at high intensity compared to low (30.6% vs. 5.8%). This trend has been observed in epidemiological studies as well, such as that by Drake et al. (2010), where higher light levels (in lux) were associated with earlier onset of severe FD in birds 17-20 weeks of age. However, rearing and keeping hens in dim lighting environments can impact normal eye development and the ability to perform important visually-dependent behaviours such as feeding and system navigation (Prescott, Wathes, and Jarvis 2003; National Farm Animal Care Council 2017), thus potentially leading to injury and poor welfare.

Overall, both lighting level management and de-beaking only serve to control FP behaviour, rather than address the underlying factors contributing to its development and persistence. Furthermore, as high light intensity and birds with intact beaks often result in greater FP in flocks, they are also considered risk factors for FP. As neither completely prevents FP behaviour, this points to a need for additional or alternative management strategies that combat a wider range of risk factors.
1.7 Methods of Feather Pecking and Feather Damage Assessment

Assessment of FP behaviour often involves direct observation of birds to either record the number of pecking bouts—which can be used to estimate the proportion of a flock performing FP (e.g., Lambton et al. 2010)—or record the frequency of pecks per individual to determine average rates of FP within flocks (e.g., Nicol et al. 1999). Direct recording of behaviour is beneficial in that low rates of FP can be captured (Lambton et al. 2010); however, it can be difficult and time consuming to perform, especially if applied in commercial settings. Alternatively, the scoring of FD can be used as a proxy for FP and provide an indirect estimation of the intensity of the behaviour.

Numerous FD scoring schemes exist, which assess different arrays of body parts on varying ordinal scales. Some of the more extensive scoring systems include those developed by Tauson (1984) using scores of 1 to 4 (worst - best) on 5 body parts, Bilčík and Keeling (1999) using scores of 0 to 5 (best - worst) on 11 body parts, and Bright et al. (2006) using a scale of 0 to 4 (best - worst) on 5 body parts. Commonly scored body areas within these systems include the neck, breast, back, rump, wings, and tail. The scales of these systems range from intact feather cover with no damage, to the presence of ruffled feathers or a few feathers missing, to substantial damage indicated by bald patches measured by centimeters or percentage of area affected (Bilčík and Keeling 1999; Bright, Jones, and Dawkins 2006). In contrast, other schemes such as those used in the welfare assessment protocols of Welfare Quality® (Welfare Quality 2009) and AssureWel (University of Bristol 2013), use simplified 3-point scales ranging from 0 – 2 indicating no damage, moderate wear or small bald patches (< 5 cm), and large bald patches (> 5 cm). Certain scoring systems such as Welfare Quality®, AssureWel, and Bright et al. (2006),
operate under visual assessment only, while others like Tauson (1984) and Bilčík and Keeling (1999), require capture and handling during assessment. Visual methods of scoring have been validated and shown to provide reliable results when compared to handling methods, with the additional benefit of being quicker and less stressful for birds (Bright, Jones, and Dawkins 2006; Kjaer et al. 2011; Giersberg, Spindler, and Kemper 2017).

1.8 Implications of Feather Pecking on Bird Welfare

FP behaviour and the FD and feather loss that it causes, compromises bird welfare in numerous ways. Firstly, the pulling out of feathers is painful for individuals receiving severe feather pecks, as indicated by noticeable agitation, vocalisation, and immobility after the removal of multiple feathers (Gentle and Hunter 1990). Damaged feather cover leaves skin susceptible to damage due to abrasion from the housing equipment in densely populated systems (European Food Safety Authority 2005). Furthermore, when FP is persistent, completely denuded areas of skin can develop, allowing birds to become vulnerable to tissue pecking and cannibalism where mortality due to blood loss often follows (Savory 1995). Cannibalism can be responsible for high proportions of mortality. In furnished cages, levels have been reported at 8.7% (Sherwin, Richards, and Nicol 2010) and even represent over 65.5% (Weitzenbürger et al. 2005) of all deaths in this system, while prevalence of cannibalism in non-cage systems has been seen to reach 20-40% (Blokhuis et al. 2007).

Aside from the acute pain and death due to FP behaviour, FD and feather loss can put stress on birds throughout the production period. Feathers are important structures unique to birds that are important for thermoregulation/insulation and water-proofing (van Zeeland and Schoemaker 2014); for locomotion such as flight, wing-flapping and navigation of the housing system
(LeBlanc et al. 2016; LeBlanc et al. 2018); and for social communication, such as displays of aggression and mating (Scanes 2015). Regarding thermoregulation and energy expenditure, the loss of feathers can be a huge metabolic stressor, as the regeneration of feathers can result in the replacement of up to 30% of a bird’s body mass (reviewed by Rubinstein and Lightfoot 2014). As a result of FD and feather loss, birds may struggle to maintain body temperature due to heat dissipation from major body areas such as the neck, back, breast, and vent area (Tullet, Macleod, and Jewitt 1980; Glatz 2001; Tauson et al. 2006). To compensate for this energy loss and reduced feed conversion efficiency (Leeson and Morrison 1978; Glatz 2001; Su, Kjaer, and Sørensen 2006), birds must, therefore, increase their feed consumption. Some birds may increase consumption by up to 30-40% (Tauson et al. 2006). Other studies found that poor feathering of the neck and breast regions led to a 10% increase (Tullet et al. 1980) and 16% increase in feed consumption (Glatz 2001).

With respect to movement and housing system navigation, LeBlanc et al. (2016) found that birds with poor wing-feathering spent less time perching and had decreased ability to wing-flap for balance while landing. LeBlanc et al. (2018) additionally demonstrated that hens employ wing-assisted incline running to ascend ramp inclines steeper than 40°. The findings of both studies highlight the importance of an intact integument for successful movement throughout the housing system and avoidance of injury, especially in aviaries.

1.9 Beyond the Bird – Implications for Farmers and Consumers

Along with the poor quality of life that millions of laying hens annually face due to FD, farmers can be significantly affected economically. FD and feather loss causes birds to increase feed consumption to maintain body temperature, thus introducing the burden of higher feed cost on
the egg farming community (Tullet, Macleod, and Jewitt 1980; Glatz 2001). Furthermore, egg production is reduced when there are flock mortalities due to cannibalism (Johnsen, Vestergaard, and Nørgaard-Nielsen 1998; Blokhuis et al. 2007), and when birds are ill or are expending undue energy on body temperature maintenance and feather re-growth (Gunnarsson et al. 1995; Johnsen, Vestergaard, and Nørgaard-Nielsen 1998; Glatz 2001). Farmer job satisfaction diminishes as well when working in a daily environment where the flock is poorly feathered and overall flock health is suboptimal, as revealed through more qualitative research on farmer attitudes to FP (Palczynski et al. 2016).

In conjunction with a well-feathered flock resulting in greater job satisfaction among farmers, Palczynski et al. (2016) found that farmers credited good feather cover with leaving visitors, such as customers or auditors, with a good impression of their farm. Good impressions are very important to consumers, as they are becoming increasingly interested in where their food comes from and what determines a quality product, with many believing that the foundation of trust is transparency (The Canadian Centre for Food Integrity 2017). A 2017 web-based survey of Canadian consumers found that 67% of participants felt farmers were most responsible for providing transparency, most of all for the well-being of production animals (The Canadian Centre for Food Integrity 2017). When animal health and welfare is not maintained, this trust can be broken and consequently affect outlook on egg farming practices and future demand. This was suggested by the findings of Bennett et al. (2016) in their survey of UK consumers, in which 40% of consumers—when learning of significant welfare problems associated with free-range farming—changed their attitude to what they had previously considered a welfare ‘gold-standard.’
1.10 Changing Attitudes Towards Egg Farming

In Canada, consumers hold a positive outlook on eggs due to their affordability and health benefits (EFC 2017). Over recent years, the demand for eggs has continued to grow, as evidenced by the steadily increasing sales of table eggs over 11 consecutive years, which is predicted to continue into the future (EFC 2017). In 2017 alone, over 732 million dozen eggs were produced by 24.5 million hens in production (EFC 2017). Paired with this industry growth, however, is rising consumer concern for animal welfare, most notably for laying hens in conventional cage housing. One leader in this charge is the United Kingdom, where in 2017, 52% of consumers bought free-range meat or eggs for environmental and/or animal welfare reasons – a figure representing a 32% increase from 2016 according to the 2017 Ethical Consumer Markets Report (Ethical Consumer 2017). Response to concern for laying hen welfare has even been followed by legislative decisions in the European Union, where conventional cages were banned from use after 2012 (European Commission 1999).

Consumer concern for animal welfare has also grown in Canada as evidenced by the increased variety of egg options available at local supermarkets such as cage-free specialty eggs (free-run, free-range, organic, and nutrient enhanced). The market for eggs from alternative housing systems is beginning to stretch beyond the boundaries of a niche market. A study in British Columbia for example reported that over a 2-year period from 2007-2009, consumption of specialty eggs rose from a combined 8% to 33% for free-range eggs and 12% for organic eggs (Bejaei, Wiseman, and Cheng 2011). In Ontario, Cranfield and Henson (2009) found from a survey of 2000 Guelph residents randomly selected from a Guelph Food Panel in 2008, that people’s choices to buy free-run and free-range eggs corresponded with animal welfare
Awareness, as well as how they felt about conventional cage housing. Other studies assessing consumers’ egg purchasing behaviour through nationwide choice experiment surveys also suggest Canadians are willing to pay premiums for free-run, omega-3 enhanced, and organic egg varieties, as described by Huang (2013), and for free-run and free-range eggs, but not for eggs from furnished cages, as described by Wang (2014). It is important to note, however, that choice experiment studies can be prone to hypothetical bias, where study participants report a willingness-to-pay greater than what their choices actually reflect.

Driven by these changing consumer attitudes, many large corporations such as Canada’s major grocers (Loblaw Co. Ltd., Metro Inc., Sobeys Inc., Walmart Corp.), and restaurants including Tim Hortons®, McDonald’s®, and Burger King® have committed to stocking and serving only cage-free eggs by 2025 (Noakes 2016). The majority of Canadian egg farms currently house hens in conventional cages (approximately 77% of birds in production; EFC, 2017); however, this figure is set to continue to decline as Canada is transitioning out of conventional cages and into alternative housing such as furnished cages, single-tier floor systems, and multi-tier aviaries – a goal to be realized by 2036 (National Farm Animal Care Council 2017).

1.11 Study Goal and Objectives

From all the available literature contributed by research on FP over the past 100 years, it is clear that FP is multifactorial. It can have severe welfare implications due to the FD and feather loss experienced by birds subjected to this behaviour, as well as economic consequences for farmers and loss of consumer trust. FP behaviour occurs in all types of housing systems, though, because FP can spread within a flock through social learning, it is of particular risk for non-conventional cage housing systems where birds are housed in significantly larger groups. Despite a broad
understanding of associated factors of FP led by predominantly European-based research, the causes of FP and resultant FD have yet to be fully elucidated. There has been comparatively little investigation of FP and FD on North American farms. With Canada’s impending shift towards alternative systems, there is a need to investigate potential risk factors and assess their effect on FP and FD on Canadian farms.

The overall goal of this study was to investigate FD on a large scale for the first time in Canada using epidemiological methods. More specifically, the objectives were to (1) identify and quantify associations between FD and reported risk factors in the areas of management, environment, and genetics of Gallus gallus domesticus laying hens; (2) provide farmers with the strategies to prevent FD; and (3) give them the tools to assess and monitor feather cover. More specifically, these three objectives were achieved by (i) first designing a simplified scoring system to measure existing FD in current Canadian flocks to use as an indirect indicator of FP activity; (ii) designing a questionnaire to survey farmers about housing and management practices, using a cross-sectional approach; and (iii) performing regression modelling to determine which factors showed an association with FD.
REFERENCES


Chapter 2: Development of a Scoring System to Assess Feather Damage in Canadian Laying Hen Flocks

2.1 Abstract

Feather damage (FD) due to feather pecking behaviour is an ongoing welfare concern among commercial egg laying hens. Canada’s current transition from conventional cage housing to alternative housing systems, where FD can spread easily within large flocks, underlines the need for frequent and accurate assessment of plumage condition. A standardized methodology for assessing FD in Canada does not yet exist. With the goal of improving and increasing FD assessment on commercial farms, a FD scoring system and visual scoring guide were developed for use in Canada. Here, FD encompasses both the destruction of feathers and their loss. Two existing plumage scoring systems, LayWel and AssureWel, which differ in level of detail and use of bird handling, were assessed for ease of use, and intra-and inter-observer reliability. Practical application of the AssureWel scoring system was greatest, with strong intra- and inter-observer reliability for the back region of the body (weighted kappa = 0.88 for both measures). This informed the creation of a modified version of the AssureWel system, including 3 scoring levels (0: fully feathered, 1: damaged feathers or a naked area smaller than a 2-dollar coin, 2: poorly feathered with a naked area larger than a 2-dollar coin) and the scoring of 50 birds per flock through visual assessment only. An accompanying guide was developed including sampling instructions, and depictions of the scoring scheme, both written and visual. This simplified and reliable scoring system will serve as a benchmarking tool for FD prevalence, and allow for future effectiveness assessments of management strategies to prevent and control FD.

Keywords: Feather damage, scoring, visual, reliability, poultry
2.2 Introduction

Feather pecking (FP) is a serious and learned behavioral problem in laying hen flocks (Zeltner, Klein, and Huber-Eicher 2000), which leads to feather damage (FD) and in more severe cases, to cannibalism and great economic loss to the farmer (Johnsen, Vestergaard, and Nørgaard-Nielsen 1998). An intact feather cover serves many functions of which the most noticeable is enabling a bird to move, fly, and navigate their environment (van Zeeland and Schoemaker 2014), which is especially important in non-cage housing systems (LeBlanc et al. 2016). A non-intact feather cover is a multifactorial problem with potentially different underlying aetiologies and associated risk factors (as reviewed by Rodenburg et al. 2013; Nicol et al. 2013). The dilemma farmers face is being aware of and determining the extent of FD in commercial flocks of laying hens to identify and treat feather cover issues early on. It is therefore important to assess and monitor the presence and severity of FD as a proxy for FP, as direct observation of FP behaviour can be difficult and time consuming to observe in commercial settings. Continuous FD assessment assumes an easy to handle and accurate scoring tool available to farmers.

Numeric rating scales for FD scoring schemes have been developed and employed in past studies on the topic of FP and FD. Current scoring methods differ in the amount of detail they record with certain scoring systems using comprehensive 4-6 point scales (Bilčík and Keeling 1999; Bright, Jones, and Dawkins 2006; Tauson et al. 2006). Detailed scoring scales allow the capture of more comprehensive information regarding severity or extent of damage, rather than simple presence or absence. These scoring systems range from including information on intact feather cover or no damage, to the presence of ruffled feathers or few feathers missing, to substantial damage, such as bald patches indicated in size by centimeters or percentage of area affected.
(Bilčík and Keeling 1999; Bright, Jones, and Dawkins 2006). In contrast, other schemes such as those used in the welfare assessment protocols of Welfare Quality® (Welfare Quality 2009) and AssureWel (University of Bristol 2013), use more condensed 3-point scales ranging from scores of 0 – 2 indicating no damage, moderate wear or small bald patches (< 5 cm), and large bald patches (> 5 cm). Some frequently used schemes such as the LayWel system (Tauson et al. 2006) do not provide descriptive definitions of their scores, but rather provide photographs as reference (1 – 4 scoring scale), while the AssureWel system provides both definitions of scores (0 – 2 scale) and photographs (University of Bristol 2013).

FD scoring methodology also differs in the type of feathers to be assessed (i.e. body or flight feathers; Bilčík and Keeling 1999; Bright, Jones, and Dawkins 2006), the number of body areas to be assessed (ranging from 3 to 11 areas; Bilčík and Keeling 1999; Bright, Jones, and Dawkins 2006; Welfare Quality 2009; University of Bristol 2013), and whether or not birds are captured and handled during assessment. Bright et al. (2006) and Kjaer et al. (2011) showed that a visual assessment of laying hens gave results similar to when birds were captured and handled, and was considered less stressful for the birds.

In general, systems with greater scoring categories and a high number of body areas to be scored are more time-intensive and achieving reliability between observers is more difficult (Main et al. 2012; D’Eath 2012) than when using simplified systems with few categories and body areas for assessment. While simplified systems can therefore be more easily implemented commercially, categories that still accurately reflect FD severity and target known body areas affected by FD are important for valid assessment.
Currently, there is no standardized program applied on Canadian egg farms to consistently record the prevalence of FD, though some farms might apply their own scoring systems as part of their animal care program. Due to the fact that Canada has committed to ban conventional cages and is transitioning to completely furnished cage and non-cage housing systems (National Farm Animal Care Council 2017), where intact feather cover will be key to bird welfare, farmers’ awareness of feather cover care and early identification and treatment of feather cover issues will be crucial.

The goal of this project was to develop a valid, accurate, reliable, and feasible FD scoring system that could be applied on commercial farms in order to have a nation-wide, standardized methodology for assessing feather cover in laying hens. Specific objectives were to (i) evaluate the reliability of two existing scoring systems, using a detailed system (LayWel) versus a simplified alternative (AssureWel), (ii) assess these two system’s timeliness and ease, and (iii) adjust their attributes to suit the Canadian commercial setting.

2.3 Materials and Methods

Reliability testing was conducted on laying hens involved in current FP research on the University of Guelph campus. Non-beak trimmed white Leghorn hens (approx. 64 weeks of age) were housed in floor pens in groups of approximately 9 birds/pen. The sample size used was 50 birds per flock as it is the sample size advised by the AssureWel system, and has been used previously in FP related studies such as those by de Haas et al. (2014) and Heerkens et al. (2015). Main et al. (2012) also noted that a sample of 50 birds was the maximum number of birds that could be reasonably assessed within the time available without incurring additional costs to farmers.
2.3.1 Intra-Observer Agreement – Instrument Reliability

A naïve member of the research team (without previous experience with the scoring system) scored for FD from outside the pens per the LayWel and AssureWel systems and this was repeated several days later to estimate intra-observer reliability. Scoring was done from outside the pens to mimic commercial conditions where producers will be asked to visually inspect their birds to increase the feasibility of the methodology. As such, only body areas visible without handling the birds were assessed (i.e., neck, back, wings and tail) while body areas that were not visible were excluded (i.e., vent and breast). Additionally, an overall score was assigned based on the general appearance of the entire bird.

The second session of testing by one non-naïve member of the research team (had been introduced to the scoring system in previous sessions) was conducted using only the AssureWel system, to further assess the intra-observer reliability of the simplest available scoring system after inter-observer testing showed promise.

2.3.2 Inter-Observer Agreement – Instrument Validity

A second naïve observer was included in further sessions to estimate inter-observer reliability using each scoring system, again using only easily visible body areas consistent with those scored during the intra-observer sessions. The inter-observer reliability assessment coincided with FD assessment performed for a separate, unrelated experiment. Due to the nature of this experiment, capture and handling of a larger sample of 117 birds was instead conducted using the LayWel scoring system, while birds scored using the AssureWel system were tested by visual assessment only and on the established sample of 50 birds. Additionally, observers
recorded the presence or absence of a naked patch of skin as a singular scoring feature to see if scorers could agree on an absence of feathers, even if the exposed skin area was very small.

Weighted Kappa (WK) values were calculated to correct for agreement by chance while taking into consideration the ordinal nature of the data, thereby also accounting for the extent of the disagreement between results (Watson and Petrie 2010). Kappa values were interpreted following the suggested classifications put forth by Landis and Koch (1977) and presented in Petrie and Watson (2013) where \( \kappa \leq 0.20 \) is ‘poor’, \( 0.21 \leq \kappa \leq 0.40 \) is ‘fair’, \( 0.41 \leq \kappa \leq 0.60 \) is ‘moderate’, \( 0.61 \leq \kappa \leq 0.80 \) is ‘substantial’, and \( \kappa > 0.80 \) is ‘good’. All agreement calculations were performed using SAS statistical software, version 9.3 (SAS Institute Inc., Cary, NC, USA).

2.3.3 Scoring System Modifications

The reliability results and time-to-completion of each assessed scoring system were used to inform a modified scoring system from those tested. Following this, supplementary documents were constructed to aid farmers in the use of the system on farm. A FD scoring guide was produced, which includes photographic references of each score for both white- and brown-feathered birds, presents all features of the scoring system, the sample size required from each flock, and instructions on how best to sample birds randomly from all areas of the barn similarly as recommended by the AssureWel system (University of Bristol 2013) and Welfare Quality project (Welfare Quality 2009). Additionally, scoring sheets were created including the photographic scales and a real scale size reference for featherless areas, which allowed for organized recording of scores for both white and brown birds.

The final system and supplementary materials were reviewed by staff at the University of Guelph’s Arkell Poultry Research Station as well as nearby farms to ensure clarity of instructions.
and feasibility of the procedure. Three Arkell staff members were given a scoring sheet and the scoring guide to assist with hen scoring. Each member randomly selected 50 different white hens to score within a small flock housed in furnished cages. Their time to completion was recorded to estimate how long the scoring procedure might take on a commercial farm. A short discussion followed with the staff regarding the ease of the scoring system and their thoughts on its application under commercial conditions. Analysis was performed to assess how well each staff member’s scores compared in their overall estimate of FD within the flock.

2.4 Results

2.4.1 Intra-observer Agreement – Instrument Reliability

Results of the first intra-observer reliability session are presented in Table 2.1. WK values for the LayWel scoring system were moderate to substantial, with least reliability for the neck region. The AssureWel system showed moderate to good WK depending on the body region, with the back showing the greatest reliability among the individual body regions.

The second session of intra-observer reliability testing was conducted with the AssureWel scoring system after AssureWel showed more promising WK values in the first session. These results showed considerable improvement for neck and back regions as well as for the overall score. Wings and tail regions continued to show weaker kappa values (Table 2.2).

2.4.2 Inter-observer Agreement – Instrument Validity

The agreement figures for inter-observer reliability between the two researchers are presented in Table 2.3. This initial assessment showed that for the neck, good WK values were achieved using the LayWel system, but for the back, no WK could be calculated due to the fact that one observer used more score categories than the other. This issue had been addressed by the time
inter-observer reliability scoring began with the AssureWel system. With this scoring system, both the neck and back area showed substantial to good WK values. In contrast, lower levels of agreement were found for the wings and tail area between observers.

Additionally, observers recorded the presence or absence of a naked patch of skin as a singular scoring feature to see if scorers could agree on an absence of feathers, even if the exposed skin area was very small. At this stage, no size limitation was placed on the naked area. This scoring feature showed high levels of agreement (92%) and a strong kappa value (k = 0.84 ± 0.08) based on the assessment of 50 birds.

During reliability testing, the AssureWel system took approx. 30 min per 50 birds to complete, while the LayWel system was more time-intensive at approx. 50 min per 50 birds.

2.4.3 Final Feather Damage Scoring System

After assessment of both the more detailed LayWel system and the simplified AssureWel system, the final scoring system decided upon by the research team was a modification of the AssureWel scheme, presented in Table 2.4 and Figure 2.1. The three scoring categories and their general descriptions were retained as well as the sample size of 50 birds per flock. The body areas to be scored were limited to just the back/rump region, and the size indicator of featherless skin for scores 1 and 2 was changed to that of a Canadian 2-dollar coin.

2.4.4 Testing in Arkell

On average, the Arkell farm staff took approx. 30 min to complete the FD scoring protocol for 50 birds. Overall, staff’s scores compared fairly well to each other in terms of percentage of the flock classified as score 0, 1, and 2 among raters. For scoring of back FD, on average 94.7% of
the flock was given a score of 0 with a maximum difference of 12% between raters, and 5.3% of the flock was given a score of 1 with a maximum difference of 12% between raters.

2.5 Discussion

Assessment of the existing plumage scoring systems, LayWel and AssureWel, informed the modification and refinement of the AssureWel scoring system into a version for application in Canada. Neither of the researchers had prior experience with assessing FD and so would be more representative of the general farmer who would be scoring the birds. Due to the nationwide data collection for this project, the research team would not be able to collect this data in-person due to travel constraints. As farmers would not be trained beforehand, it would be important that the scoring system is understandable and accurately applicable during first-time use, and feasibility of the methodology would be crucial. On a personal level, the researchers found the AssureWel system easier and faster to use than the illustrated 4-point scale of the LayWel system, and it was anticipated this would be the same for farmers. Previous studies have shown that with more detailed scoring scales there is more room for disagreement and more training is required compared to simpler scoring systems, leading to the recommendation of using a scoring system with fewer categories (D’Eath 2012).

Using a 3-point scale allowed for the most concise representation of FD condition as it provided a score that reflected an unaffected bird with intact feather cover, as well as both an intermediate score for birds with moderate damage, and a score for birds severely affected with a prominent bald patch. The back/rump area was selected as the only body region for scoring as it consistently showed the highest level of agreement among the regions tested, is an area typically most targeted by FP behaviour (Wood-Gush and Rowland 1973; Green et al. 2000; Rodenburg et
al. 2013), and where FD and naked patches are least likely to be caused by abrasion from the housing system (Bilčík and Keeling 1999). Previous observational studies have used the back as a key area for FD observation as well (Bestman, Koene, and Wagenaar 2009; Gilani, Knowles, and Nicol 2013). Other body areas, such as the wings and tail, were not incorporated in the final scoring system because scoring of these areas was inconsistent, i.e. showed low levels of agreement between raters, even with the simplified scales of the AssureWel system. Limiting assessment to the back region allows for a swift and reliable scoring procedure and FD assessment.

The use of a binary scale to measure the presence or absence of a naked patch to further increase feasibility and reliability was also assessed. Inter-observer reliability for this singular measure was high, but it was feared that it would lead to a loss of information regarding severity and extent of FD in flocks that could be captured with a three-point scoring scale, especially considering that farmers typically tend to score lower than researchers (D’Eath 2012).

With respect to the literature, an inter-observer WK of 0.88 was reached for the back area between researchers, similar to values reported by Kjaer et al. (2011) who found a WK of 0.82 between researcher teams using a visual assessment of plumage damage. Between farmers, lower values are reported (kappa of 0.50) when ranking photographs of FD damage only (Palczynski et al. 2016). Some variation between assessors’ perceptions as to what is considered an acceptable level of FD is also unavoidable (Main et al. 2012; Palczynski et al. 2016), therefore written descriptions and visual depictions of each score were included in the final system. In a trial of the modified system with the accompanying scoring guide, the three Arkell research staff who scored 50 birds within the same room (and thus likely scored different birds) found fairly similar
FD prevalence suggesting that it gave a reasonable representation of all birds within the room. Staff members also found the system easy to use, with clear straight-forward instructions provided by the scoring guide.

Intra-observer reliability of FD scoring increased after multiple sessions. It should be noted that this reflects a slight learning effect on the part of the researchers in that with more practice and experience, reliability among raters can improve (D’Eath 2012). In addition to fewer scoring categories and body areas, this effect may also have played a part in the AssureWel system being faster to perform. Unfortunately, providing farmer training and assessing reliability of farmer FD scoring was outside the scope of this project and this limitation should be acknowledged. However, farmers are free to use the visual aids and instruction material, which could increase their ability to accurately score FD within their flocks. Furthermore, the modified system employs methods very similar to the AssureWel scheme already in use for FD assessment on farms. As such, this scoring system is likely a valuable tool for benchmarking FD prevalence, especially with consistent use over time as farmers get more familiar with the system.

Further considerations to increase reliability of farmer collected FD scores were made to tailor the scoring system to Canadian farmers and provide a clear size indicator for the damaged area. As mentioned, in the assessment of inter-rater reliability for the presence of a naked patch, initially no size indicator was set. Most existing scoring systems define this in terms of centimeters or percentage of area affected, which can be difficult to estimate in commercial settings, and/or without practice. Therefore, the naked patch size stipulation was modified to that of a Canadian two-dollar coin, or “Toonie”, rather than a specific linear measurement, to provide farmers with a size reference that could be easily visualized. The toonie is unique to Canada, is
something that most farmers are familiar with in terms of size, and is something that could be easily carried with them for help during scoring. A naked patch of that size, especially on the back region where damage to this area is almost exclusively caused by FP activity (Bilčík and Keeling 1999), would also be a sufficient indicator of this behaviour in a flock.

2.6 Conclusion

This study provides a rationale for the development of a feather damage (FD) scoring system, which can be applied on commercial farms where birds are housed in furnished cage and non-cage housing systems, i.e., in Canada. This scoring system, modified from the existing AssureWel protocol, has been found to be reliable (weighted kappa = 0.88), can be easily used by farmers to assess and monitor FD within their flock, and ultimately allows for benchmarking of FD prevalence. This scoring tool will be essential for future effectiveness assessments of management strategies to prevent and control FD.
REFERENCES


**TABLES**

**Table 2.1.** Intra-observer reliability of feather damage (FD) scoring in laying hens based on two existing scoring systems using numeric scales (LayWel, 1-4 scale and AssureWel, 0-2 scale). Different body areas were assessed and one overall score was given based on overall impression of the hen. Reliability was assessed as weighted kappa (WK).

<table>
<thead>
<tr>
<th>Body Area</th>
<th>LayWel</th>
<th>AssureWel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Weighted kappa (WK)</td>
</tr>
<tr>
<td>Neck</td>
<td>53</td>
<td>0.49</td>
</tr>
<tr>
<td>Back</td>
<td>53</td>
<td>0.72</td>
</tr>
<tr>
<td>Wings</td>
<td>52</td>
<td>NA</td>
</tr>
<tr>
<td>Tail</td>
<td>51</td>
<td>0.74</td>
</tr>
<tr>
<td>Overall</td>
<td>53</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Table 2.2.** Intra-observer reliability of feather damage (FD) scoring in laying hens based on the AssureWel scoring system (0-2 scale) following initial testing. Different body areas were assessed and one overall score was given based on overall impression of the hen. Reliability was assessed as weighted kappa (WK).

<table>
<thead>
<tr>
<th>Body Area</th>
<th>AssureWel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Neck</td>
<td>54</td>
</tr>
<tr>
<td>Back</td>
<td>54</td>
</tr>
<tr>
<td>Wings</td>
<td>54</td>
</tr>
<tr>
<td>Tail</td>
<td>54</td>
</tr>
<tr>
<td>Overall</td>
<td>54</td>
</tr>
</tbody>
</table>

**Table 2.3.** Inter-observer reliability of feather damage (FD) scoring of different body areas in laying hens based on two existing scoring systems using numeric scales (LayWel, 1-4 scale and AssureWel, 0-2 scale) between two principal members of the research team. Reliability was assessed as weighted kappa (WK).

<table>
<thead>
<tr>
<th>Body Area</th>
<th>LayWel</th>
<th>AssureWel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Weighted kappa (QK)</td>
</tr>
<tr>
<td>Neck</td>
<td>117</td>
<td>0.82</td>
</tr>
<tr>
<td>Back</td>
<td>117</td>
<td>NA</td>
</tr>
<tr>
<td>Wings</td>
<td>117</td>
<td>0.58</td>
</tr>
<tr>
<td>Tail</td>
<td>116</td>
<td>0.74</td>
</tr>
</tbody>
</table>
Table 2.4. The scoring system used by farmers on-site to evaluate the feather condition and amount of feather damage present in their flock. Body areas scored were limited to the back/rump on a sample of 50 birds per flock.

<table>
<thead>
<tr>
<th>Score</th>
<th>Body condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Intact feather cover, no or slight wear, only single feathers missing</td>
</tr>
<tr>
<td>1</td>
<td>Damaged feathers (worn/deformed) or bald patch visible ≤ a $2 coin</td>
</tr>
<tr>
<td>2</td>
<td>At least one bald patch visible that is &gt; a $2 coin</td>
</tr>
</tbody>
</table>
Figure 2.1. Visual representation of the developed scoring system for both white- and brown-feathered birds. A&D: score 0, B&E: score 1, C&F: score 2.
Chapter 3: A Cross-sectional Study on Feather Cover Damage in Canadian Laying Hens in Non-Cage Housing Systems

3.1 Abstract

Non-cage housing systems are increasingly being used worldwide in efforts to improve laying hen welfare. However, feather damage (FD) due to feather pecking remains a welfare concern in these systems where birds are housed in large groups. The aim of this study was to identify bird, housing, and management associations with FD in laying hens in non-cage housing systems in light of Canada’s commitment to phasing out conventional cages. A questionnaire encompassing housing and management practices was developed and distributed to 122 laying farms nationwide in autumn of 2017 (response rate of 52.5%), providing information on a subset of 39 flocks housed in non-cage systems. Prevalence of FD was visually assessed by farmers using a simplified FD scoring system (0: fully feathered, 1: damaged feathers or a naked area smaller than a 2-dollar coin, i.e. about 28mm in diameter, 2: poorly feathered with a naked area larger than a 2-dollar coin). Fifty birds proportionately selected from the litter, slatted area and tiers were assessed and the percentage of birds with FD (score > 0) was calculated. Variables that met the univariable selection criteria (P < 0.25), or were considered biologically relevant, were used in preliminary multivariable linear regression modeling. “Litter provision”, “frequency of manure removal/manure belt operation”, “bird age”, “enrichment provision”, “matching of rearing and laying environment by providing litter substrate”, and “provision of a dawn/dusk period” were included in the final model and accounted for 64% of the variation in FD between farms. Age (+0.9% ± 0.29) and housing of birds in all wire/slatted barns compared with all litter barns (+37.6% ± 13.1) were associated with higher prevalence of FD. Additionally, on farms where manure was removed only after the flock was depopulated, FD prevalence tended to be
higher (+20.1% ± 10.70). Provision of enrichment also tended to be associated with higher FD (+19.1% ± 8.04), a possible indication that enrichment was provided as a control measure after FD was observed or enrichment could not make up for other underlying factors contributing to FD. These results highlight the importance of providing litter substrate and proper litter management (e.g., via prevention of manure accumulation on litter substrate) to reduce FD among laying hens in non-cage housing systems in Canada. However, these practices need further examination in longitudinal and/or intervention studies on commercial farms to assess their use as management strategies to prevent FD in hens housed in non-cage systems.

**Keywords:** laying hen, feather damage, aviary, floor system, welfare

### 3.2 Introduction

Canadian egg production has grown over the past 11 years, with a 4.1% increase from 2016 to 2017 in the sale of table eggs – a trend predicted to continue throughout 2018 due to consumers’ positive outlook on eggs and their associated health benefits (EFC 2017). With this growth in egg consumption comes a growing consumer interest in enhanced animal welfare standards and a market for cage-free specialty eggs (free-run, free-range, organic, and nutrient-enhanced). This interest is demonstrated, for example, by a study in British Columbia in which consumption of specialty eggs rose from a combined 8% to 33% for free-range eggs and 12% for organic eggs over a 2-year period (Bejai, Wiseman, and Cheng 2011). Canada’s major grocers and other food corporations such as McDonald’s® and Tim Hortons® have also contributed to this shift, pledging to buy only cage-free eggs by 2025 (Noakes 2016).

In light of changing market trends, Canadian egg farming is transitioning away from conventional cage housing of hens and into furnished cage and non-cage systems, such as single-.
tier floor systems and multi-tier aviaries (National Farm Animal Care Council 2017). Though these housing systems offer birds the space and resources to better perform natural behaviours, they pose welfare risks in other ways, most notably a greater opportunity for feather pecking (FP) behaviour and resulting feather damage (FD). FP is the action by which hens peck or pluck at, and sometimes eat the feathers of their conspecifics, causing FD (feathers that are broken, deformed, or deviate from a smooth and intact state) and feather loss typically on the back/rump, vent, and tail areas (Savory 1995; McAdie and Keeling 2000; Glatz 2001). Loss of feather cover can eventually progress to tissue pecking and mortality due to cannibalism (Savory 1995).

Feathers are integument features unique to birds and are critical for survival in wild birds. They are smooth, flexible structures largely composed of beta-keratin protein (Scanes 2015). The various feather types distributed over the body enable birds to carry out locomotive behaviours such as flight or wing-flapping to escape predators and navigate the environment (LeBlanc et al. 2016; LeBlanc et al. 2018), reproductive and social behaviours such as mating displays and shows of aggression through feather raising (Scanes 2015), as well as thermoregulatory behaviours as feathers enable birds to stay warm and dry by providing insulation and a waterproof exterior (van Zeeland and Schoemaker 2014). In the wild, feathers are kept in good shape with a large portion of the day being dedicated to maintaining their integrity through preening i.e. cleaning, restoring their structure, and applying preen oil (Scanes 2015). Feathers, much like hair and nails, when damaged cannot repair themselves, thus old feathers get shed through normal preening and replaced through the renewal process of molting (Scanes 2015). Replacement of feathers can be an immense metabolic stressor, including the replacement of up to 30% of a bird’s body mass (reviewed by Rubinstein and Lightfoot 2014) and a basal metabolic rate which can double during molting in avian species (Lindström, Visser, and Daan 1993).
Healthy and functional feather cover is just as important for domestic birds, but is much harder to maintain in hens kept in modern housing systems when FP is present. Feather cover damage due to the pecking and pulling out of feathers by other birds represents one of the more common and frustrating challenges in birds kept in intensive production systems (Hartcher et al. 2016). Epidemiological studies in Europe have shown that up to 50-80% of non-cage flocks exhibit severe FP and FD (Lambton et al. 2010; Gilani, Knowles, and Nicol 2013; de Haas, Bolhuis, de Jong, et al. 2014). The most well-accepted hypothesis as to the origin of FP is that it is a redirected foraging/feeding behaviour (Blokhuis 1986) induced by the stress and frustration of living in a barren environment, but it is ultimately multifactorial, including environmental, nutritional, psychological, and genetic factors (Rodenburg et al. 2013; Brunberg et al. 2016).

Feather loss and FD undoubtedly cause bird discomfort and present a significant welfare issue. In addition to health and well-being implications of poor feather cover, images of birds without feathers do not meet consumer expectations and increase the risk that consumers will lose trust in egg farming and the livestock food system as a whole (Bennett et al. 2016). Consumers are increasingly interested in food production practices, with a strong relationship between transparency and trust (The Canadian Centre for Food Integrity 2017). A 2017 survey indicated that farmers are those held most responsible for demonstrating trust-building transparency in regards to animal well-being (The Canadian Centre for Food Integrity 2017). Not having a fully feathered flock can thus also affect farmers through poor financial return due to flock health issues or negative consumer perceptions, but also in terms of diminished job satisfaction due to the daily visual impact of compromised bird welfare (Palczynski et al. 2016).
Elucidating the contributing factors leading to FD is thus essential for providing good welfare to millions of hens, but also for fostering continued trust between egg farmers and consumers, and consequently, sustainability within the egg farming community. Though numerous epidemiological studies have been conducted in Europe, to the best of the researchers’ knowledge, no large-scale investigations into FD have been done in North America. The goal of this study was to therefore investigate FD in the Canadian context where climate, feeding and management practices can differ considerably from those in Europe and across regions within Canada. More specifically, the objectives were to (i) identify and quantify associations between FD and reported risk factors in the areas of management, environment, health, and genetics, (ii) provide farmers with the strategies to prevent/control FD, as well as (iii) provide farmers with tools to assess and monitor feather cover.

3.3 Materials and Methods

Study objectives were achieved in three steps: 1) the design of a simplified and easy to use yet comprehensive FD scoring system that does not require handling to assess FD prevalence on-farm, 2) the design of a questionnaire based on housing features and management practices distributed to egg farmers currently using alternative systems across the country, and 3) linking farm characteristics and practices with the occurrence of FD through regression modelling.

3.3.1 Development of the Feather Damage Scoring System

Farmers scored FD in their flock using a devised visual scoring system with a three-point scale from 0 to 2 according to severity (Table 3.1) adapted from previously validated scoring schemes (Bright, Jones, and Dawkins 2006; Tauson et al. 2006; University of Bristol 2013a). Here, FD encompasses both the destruction of feathers and their loss. The back/rump was chosen as the
scoring area, as this is a region of the body typically most targeted in FP and where feather loss is unlikely to be caused by other conditions i.e., abrasions from the system (Bilčík and Keeling 1999; Nicol et al. 2013). The newly developed, simplified scoring system prioritized ease of use and time efficiency i.e., visual assessment rather than capture and handling. Using three scoring categories allowed the incorporation of both good and poor feather cover extremes along with an intermediate score for birds not severely affected by FP. Previous research has validated the use of visual assessment compared to the capture and handling of birds for assessing their feather cover (Bright, Jones, and Dawkins 2006; Giersberg, Spindler, and Kemper 2017).

Inter-observer reliability was determined by scoring laying hens at the University of Guelph. Furthermore, efficiency of the scoring system was assessed at Arkell Poultry Research Station (University of Guelph) as well as on local farms representing the three non-conventional cage housing systems investigated. Staff were instructed to score birds as the scoring procedure dictated to ensure that instructions were clear to participants and could be easily followed. Time taken to complete FD scoring was also recorded to estimate duration of the process in a commercial setting (approx. 30 min).

For the recording of FD scores, farmers were instructed to score a sample of 50 birds selected evenly across all sections of the barn as described in previous studies (University of Bristol 2013a; Heerkens et al. 2015; de Haas, Bolhuis, de Jong, et al. 2014). Detailed and illustrated instructions were provided to assist farmers with selection of birds from different tiers/rows, slatted areas and litter areas depending on the housing system. Additionally, a feather cover scoring guide with full-colour photographs of the different scoring scales for both white- and brown-feathered birds was provided to farmers to serve as an instructional tool that could be
referenced while scoring birds. Lastly, scoring sheets were provided to farmers for the organized recording of feather damage scores.

### 3.3.2 Development of the Layer Questionnaire

The questionnaire for laying hen farmers was designed with the help of the questionnaire used in a study by Lambton et al. in 2013. In that study, feather pecking in laying hens in alternative systems and its associations with management and environmental factors was investigated. This questionnaire was then tailored to comprise primarily housing and management-based questions specific to current Canadian practices and standards, using the 2017 Canadian Code of Practice for pullets and laying hens as a resource, as well as the expertise of the research team and feedback from federal and provincial egg boards. The main subsections of the questionnaire focused on flock and bird characteristics, housing features, litter management, flock health, staff duties, rearing history, diet, lighting, and air quality (Table 3.2). Questions were a mix of open-ended and closed with multiple answer options, and were provided in both English and French versions.

The questionnaire was tested by staff at the Arkell Poultry Research Station (University of Guelph) and the time taken to complete them recorded (approx. 1.0-1.5 h). In addition, the questionnaire was pilot-tested by personnel from a few commercial farms, and circulated to the provincial egg boards to receive input on how well questions reflected commercial settings, to determine if there were discrepancies in how questions would be interpreted, and to gauge overall comprehensiveness, i.e. whether the subject areas being asked about were sufficient, needed further inquiry, or could be pared down for better conciseness.
3.3.3 Questionnaire Distribution

Questionnaires were provided in both hard copy form (via mail-out to participating producers) and electronically (via Qualtrics® online survey software (Qualtrics 2017)). Both types of administration were used in order to accommodate groups that favour the ease and speed of an online survey format, as well as groups that may not have reliable access to the Internet or refrain from its use.

The mailed-out questionnaire packages included: (1) a laying hen questionnaire, (2) a feather cover damage scoring guide, (3) two feather cover damage scoring sheets – one for white hens and one for brown hens, (4) one cover letter outlining the study with a consent form, and (5) a return-addressed envelope for the return of written responses.

Questionnaire packages were distributed through the egg boards within each province to target all relevant egg producers that housed flocks in non-cage housing systems and to ensure participant privacy while achieving geographic proportionality. Each package was assigned a 3-digit numeric code in order to ensure all package documents from a participant would remain together throughout the analysis. Distribution began October 3, 2017 and data was collected over the following three-month period through to December 31, 2017. Reminders were sent out by the provincial egg boards 2-4 weeks post initial distribution and once more two weeks before data collection ceased. This study was approved by the University of Guelph Research Ethics Board (REB17-06-010).

3.4 Statistical Methods

The data collected via the questionnaire was analyzed to determine factors associated with the prevalence of FD within a flock, as measured by the percentage of sampled birds with back
scores of 1 or 2 on each farm. All statistical analyses were performed using R version 3.4.3 “Kite-Eating Tree” (R Core Team 2017) in combination with RStudio (RStudio Team 2016).

3.4.1 Model building

The data was entered using double manual entry and checked for errors. Variables were screened to determine those with excessive missing values (> 50% of responses missing) or with insufficient variation (e.g. a binary variable with a proportion of responses approximately > 0.85), which were excluded from further investigation. Continuous variables were checked for linearity. Response categories for several variables underwent retrospective collapsing in order to create a more even distribution of responses. Following this, a total of 61 variables were included in univariable analyses. Variables, which reached the criterion of $P \leq 0.25$, or were considered biologically relevant, were retained for further investigation. To test for collinearity and unduly strong association between predictor variables, Spearman rank-correlations were estimated for continuous variables and Pearson’s $\chi^2$-tests performed for categorical variables. The remaining predictor variables (24 variables) of FD prevalence were included in multivariable analysis using a mixed linear regression model with a forward variable selection approach. Variables that were significant ($P \leq 0.05$) and/or contributed to a high adjusted $R^2$ comprised the final model. Relevant interactions between retained predictor variables were tested. The variable for flock age was centered at 40 weeks in an effort to allow for a more intuitive interpretation of FD prevalence at this age.

3.4.2 Diagnostic Procedures

Model diagnostics were carried out to assess normality of residuals using a QQ-plot (Dohoo, Martin, and Stryhn 2009). Homogeneity of variance was also evaluated graphically with a
scatterplot of standardized residuals against fitted values. Collinearity was assessed using the Variance Inflation Factor (VIF). The presence of outliers was checked using a boxplot of model residuals, and the absence of influential data points was checked using Cook’s distance.

3.5 Results

3.5.1 Response Rate

A total of 122 questionnaire packages were distributed to laying hen farms where birds were not housed in conventional cages. The number of packages returned totaled 64 (response rate of 52.5%), providing information for 65 flocks.

3.5.2 General Flock Information

Thirty-nine of the 65 flocks were housed in non-cage systems (65%), of which 17 flocks were housed in single-tier floor systems (43.6%), and 22 flocks were housed in multi-tier aviary systems (56.4%). Flock size, flock age, and FD prevalence of the non-cage flocks is presented in Table 3.3. Birds in all flocks were beak-treated at day 1 in the hatchery using an infrared laser. With respect to feather colour, 32% of birds were white-feathered and 68% were brown-feathered. Within the 30 out of 39 flocks that had available breed information, (60.0%) were a Lohmann strain, while other strains included Dekalb (6.7%), Hy-line (16.7%), ISA (10.0%), and Novogen (6.7%). A detailed description of study flocks and housing and management practices on these farms is presented in van Staaveren et al. (2018).

3.5.3 Univariable Analysis of Factors in Non-Cage Systems

Variables associated (P ≤ 0.25, or biologically relevant) with FD in non-cage laying flocks at the univariable level of analysis are presented in Table 3.4. These variables were factors related to
farmer characteristics, flock characteristics, housing features, litter management, rearing management, nutrition, and feeding and lighting practices.

3.5.4 Linear Regression Analysis for Non-Cage Systems

Floor type, the frequency of manure removal/manure belt operation, flock age, enrichment provision, matching of rearing and laying environment by providing litter substrate, and provision of a dawn/dusk period were included in the final model and accounted for 73% of the variation in FD between flocks (Table 3.5). “Age”, “floor type”, with the largest effect contributed by all wire/slatted barns, and “provision of enrichment” were significantly associated with higher FD. Additionally, FD prevalence tended to be higher with decreasing “manure belt frequency”, with the largest effect when manure was removed only at the end of lay. Not matching litter in both rear and lay, as well as not providing a dawn/dusk phase were positively associated with FD however, the associations were not significant (Table 3.5). No interactions between factors were found to significantly influence the final model.

3.6 Discussion

Using a nationally distributed questionnaire and the collection of FD scores from sampled flocks, management, environmental, and genetic factors associated with FD outcomes in laying hen flocks housed in non-conventional cage housing systems were assessed. On average, approximately one quarter of the birds within these flocks exhibited some form of FD, either moderate or severe, and factors most strongly associated with FD included increasing flock age, housing with all wire or slatted floors, manure removal only at the end of production, and provision of enrichment material.
The prevalence of FD found among participating flocks was approximately 26% (95% CI: 15.6-36.2%). This is likely an underestimation of the true prevalence of FD typically exhibited on farms in Canada since the surveyed flocks included some that were relatively young or newly brought into lay. Research on FP behaviour and resultant FD has consistently shown that both increase as birds age (Bilčík and Keeling 1999; Huber-Eicher and Sebő 2001; Lambton et al. 2013). This too is illustrated in the findings of the current study, in that a small but significant positive association between the age of a flock and the level of FD was observed (P = 0.0017). The flocks surveyed in this study were not uniform in age when scored. While younger flocks may be at risk in terms of feather pecking, they may not have begun to show signs of FD at the time of scoring. Had the study surveyed all flocks at the same age in the middle of the production period, median and mean FD prevalence are likely to have been greater in value. Previous epidemiological studies in which laying flocks were scored at the same week of age or within a specific age range past 30 weeks, such as that performed in Sweden by Gunnarsson et al. (1999), reported damage on the back area in a median of 62% of birds. In the Netherlands, Bestman and Wagenaar (2003) found moderate or severe FD in 71% of birds, and more recently, de Haas et al. (2014) found 49% of flocks displayed FD.

The hen integument is damaged in all types of housing systems (Sherwin, Richards, and Nicol 2010; Lay et al. 2011). Research suggests that FP behaviour is initiated by a small percentage of birds and proceeds to spread throughout a flock (Zeltner, Klein, and Huber-Eicher 2000; Appleby, Hughes, and Elson 1992). Therefore, housing of large flocks in non-cage systems contributes to an increased prevalence of FD (Tauson 2005; European Food Safety Authority 2005). This was found to be true in this study as a survey of Canadian furnished cage flocks yielded a prevalence of 21.9% (Chapter 4). The prevalence of 25.9% found here was low
compared to those found in the studies mentioned above. However, when comparing the proportion of birds with FD between flocks in conventional cages, furnished cages, free-run barns, and free-range systems, Sherwin et al. (2010) found proportions of birds with FD within each system (24.7%, 24.9%, 26.9%, and 15.5%, respectively), similar to the mean prevalence reported here. Their finding of barn systems having the highest prevalence of poor plumage condition suggests that non-cage systems do tend to exhibit higher levels of FD, even at proportions around 25%.

Floor type had the most significant effect on FD (P < 0.001), largely due to the effect of all wire or slatted floors, correlated with an increase in FD of approximately 38% in such flocks. Other epidemiological studies have similarly found associations with absence of litter and increased FP activity or FD, such as an absence of loose litter at the end of lay (Green et al. 2000) and restriction to the slatted area during nest box training (severe FP was 24 times more likely) (Lambton et al. 2010). This profound effect is also in line with the generally accepted notion that FP arises from a lack of foraging substrate (Blokhuis 1986; Huber-Eicher and Wechsler 1998; Dixon, Duncan, and Mason 2008) and the research demonstrating how chicks and pullets reared without suitable litter material show severe FP and poor plumage later in life (Johnsen, Vestergaard, and Nørgaard-Nielsen 1998; Nicol et al. 2001; de Haas, Bolhuis, Kemp, et al. 2014).

Low frequency of manure belt running for manure removal was the third factor associated with greater FD (P = 0.0151). Removal of manure only at the end of the production cycle contributed the most to this effect in that flocks were estimated to exhibit 20% more FD compared to those where manure was cleared more than 3 times per week. This factor is likely an indicator of air
quality, where less frequent manure removal can contribute to increased levels of ammonia in the barn. Concentrations of ammonia tend to be higher in housing systems with manure composting inside the facility compared to systems with regular manure removal such as manure belts (European Food Safety Authority 2005). This has been found in numerous studies when measuring ammonia concentrations in cage systems compared to free-run floor and aviary systems (as reviewed by David et al. 2015). Birds find ammonia aversive above concentrations of 20-25ppm where it can impair health and reduce immune function (David et al. 2015). Ammonia at this level is also aversive to barn staff and can compromise their health (Donham et al. 2000), leading to reduced care and detection of welfare issues within the flock when workers are reluctant to enter the barn. Poor air quality as a general irritant and source of stress plays into the multifactorial nature of FP behaviour, as found by Drake et al. (2010) where FD increased with higher carbon dioxide and ammonia in early lay. It is important to note that data was collected in the autumn and early winter months of October to December when ventilation begins to be reduced to conserve warmth in the barn. Decreased ventilation in colder weather paired with humid conditions inside the barn can increase litter moisture and therefore provide a better environment for bacteria to produce ammonia gas (Zhao et al. 2015), a factor which may have influence here.

Removing manure from the barn only at the end of a flock cycle can additionally impact air quality in litter systems due to high dust levels when the litter is not changed and there is poor ventilation of the facility. Dust is contributed by bedding material, feed, dry manure, skin cells, and feathers (Widowski et al. 2013). Dust and gasses can harm the respiratory system, such as through the loss of cilia needed to clear debris from the upper respiratory tract (Anderson, Beard, and Hanson 1966), as well as macro- and microscopic lesions throughout the trachea, lungs, and
air sacs (Oyetunde, Thomson, and Carlson 1978). Birds are then predisposed to secondary respiratory diseases caused by bacterial, viral, and fungal infection when the mucosa is compromised (Oyetunde, Thomson, and Carlson 1978; Anderson, Beard, and Hanson 1964). When poor air quality from a multitude of sources leads to negative health outcomes, it contributes to the stress birds experience in these systems and thus increases the risk of FP behaviour and resultant FD.

Lastly, the provision of enrichment in non-cage systems showed a tendency of association with increased FD ($P = 0.0586$) and was estimated to promote 19% more FD compared to flocks without enrichment. This finding is in opposition to the existing literature – additional foraging opportunities afforded by enrichments such as pecking blocks, hay bales, and hanging objects are viewed as effective methods of FP and FD prevention, especially during rearing (McAdie et al. 2005; University of Bristol 2013b; Jones et al. 2002). It is possible here that if birds were reared in a non-enriched environment, provision of these enrichments during the laying period were ineffective at preventing or minimizing FD, as suggested by Glatz (2000); however the questionnaire did not capture information on enrichment during rearing so this issue cannot be further investigated here. Additionally, producers that have regular issues with FP may have been the ones to provide enrichment. Within the questionnaire, follow-up questions regarding enrichment use revealed that some farms only provided enrichment in response to FD already observed in the flock, therefore the effect of enrichment for non-cage flocks should be interpreted with some caution.

It is important to note that this was an exploratory study, as it is the first of its kind in Canada, and thus the p-values exhibited should be considered exploratory (Spiegelhalter 2017). Further
investigation is needed regarding the impact of factors discussed here. Additionally, no age restrictions were imposed on flocks in lay in this study. It should therefore be recognized that the factors investigated may not have yet reflected their impact on plumage condition at the time of feather cover assessment for certain flocks newly brought into lay. Furthermore, much of the literature comprises studies conducted in Europe where some flocks were not beak-trimmed, and where free-range and organic farming is more common practice than in Canada. Different methods of FD scoring regarding scales used and number of body regions scored also make comparison among study findings difficult.

3.7 Conclusion

Overall, a FD prevalence of approximately 26% was found in a survey of laying hen flocks across Canada, indicating that FP activity is an active problem in non-cage systems within the country.

Reduced feather cover has important implications for bird welfare (thermoregulation, housing navigation difficulties, and susceptibility to injury), as well as egg farmers (economic losses, low morale or motivation, reduced public support), and consumers (loss of trust in farming practices and animal caretaking).

The investigation of housing, management, and genetic factors related to FD indicated that providing birds the opportunity to forage and dustbathe in litter areas in barns continues to be an important element in preventing FD in laying flocks. Cleanliness of the floor area, amount of manure in the barn, and air quality related to these factors should be considered in barns where manure is not removed until the end of lay; such farms could see FD improvement with more frequent manure removal and/or replacement of the litter. Finally, despite contrasting findings of
the effect of enrichment on FD outcomes, diversity of the environment through pecking objects and toys is still encouraged for use in the laying barn while attention should be given to enrichment during rearing as well. The factors discussed here would benefit from a longitudinal follow-up study to further investigate the impact of management changes in FD prevention and to better inform the egg farming community on how to prevent FD as more flocks enter alternative housing systems.
REFERENCES


TABLES

Table 3.1. The scoring system used by farmers on-site to evaluate the feather condition and amount of feather damage present in their flock. Body areas scored were limited to the back/rump. A Canadian $2 coin is 28mm in diameter.

<table>
<thead>
<tr>
<th>Score</th>
<th>Body condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Intact feather cover, no or slight wear, only single feathers missing</td>
</tr>
<tr>
<td>1</td>
<td>Damaged feathers (worn/deformed) or bald patch visible ≤ a $2 coin</td>
</tr>
<tr>
<td>2</td>
<td>At least one bald patch visible that is &gt; a $2 coin</td>
</tr>
</tbody>
</table>

Table 3.2. A summary of the housing and management information about a farmer’s current laying hen flock collected through the self-administered questionnaire.

**General Information**
- Date
- Years of farming experience
- Province
- Farm size

**Flock Information**
- Hatchery & rearing farm birds came from
- Date of placement
- Age of placement
- Current flock age
- Flock size at placement & current size

**Housing Features**
- Housing system used
- No. of system tiers
- Manufacturer & model
- Age of system
- Stocking density
- Perches (availability, height, space)
- Nests (availability, type, location)
- Drinker & feeder type
- Enrichment (types, age of access, motivation for use)

**Litter Management**
- Floor type/proportion of litter
- Type of material, depth, maintenance
- Age of access
- Restriction practices
- Supplemental foraging material

**Bird Characteristics**
- Feather colour
- Breed
<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
</table>
| Rearing and Placement  | Visitation of pullet flock  
Home-rearing vs. supplier, integration of flocks yes/no  
Pullet housing system  
Beak trimming (yes/no, age, method, length)  
Condition on arrival  
Matching of environmental conditions |
| Flock Health           | Inspection (frequency, duration, no. of workers, route, observations)  
Feather pecking (if it had been observed, body area, at what age, any management changes in response)  
Flock behaviour in response to workers  
Biosecurity measures  
Vaccination & instances of illness  
Mortality (percentage & main causes) |
| Diet                   | Feed structure, supplier, availability, supplements  
Feeding frequency & special practices (midnight feeding)  
Diet changes  
System breakdowns |
| Lighting               | Type, hours of light, intensity  
Dawn/dusk period (yes/no) & method |
| Air quality            | Type of ventilation  
Temperature, humidity, ammonia concentration, dust levels  
Manure removal frequency |
| Outdoor Access         | Type of access (veranda vs. range area), age of access  
Range (size, use, quality)  
Popholes (number, distribution throughout barn)  
Outdoor area rotation |
| Productivity           | Age at start of lay  
No. of eggs collected per day, percentage of floor eggs  
Performance compared to breed standards  
Current & peak production figures |
Table 3.3. Description of 39 laying hen flocks housed in non-cage systems by average age, flock size and prevalence of feather damage (FD).

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean (SD)</th>
<th>Median (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flock age (wks)</td>
<td>39</td>
<td>46.1 (13.87)</td>
<td>45.0 (19 – 68)</td>
</tr>
<tr>
<td>Flock size</td>
<td>37</td>
<td>13945 (10949.73)</td>
<td>11950.0 (119 – 41478)</td>
</tr>
<tr>
<td>FD prevalence (%)</td>
<td>1950*</td>
<td>25.9 (31.70)</td>
<td>10.0 (0 – 100)</td>
</tr>
</tbody>
</table>

*Total number of birds scored for FD (39 x 50)

Table 3.4. Explanatory variables (P ≤ 0.25) associated with the presence of feather damage (FD) in non-cage laying flocks (n = 39) at the univariable analysis level.

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>N* (%)</th>
<th>Coefficient</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer experience</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 10 years</td>
<td>19 (48.7)</td>
<td>Referent</td>
<td>0.1540</td>
</tr>
<tr>
<td>More than 10 years</td>
<td>20 (51.3)</td>
<td>-14.57</td>
<td></td>
</tr>
<tr>
<td>Flock age (weeks)</td>
<td>39 (100)</td>
<td>0.91</td>
<td>0.0118</td>
</tr>
<tr>
<td>Feather colour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>12 (31.6)</td>
<td>Referent</td>
<td>0.1834</td>
</tr>
<tr>
<td>Brown</td>
<td>26 (68.4)</td>
<td>14.56</td>
<td></td>
</tr>
<tr>
<td>Housing system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-tier/floor</td>
<td>17 (43.6)</td>
<td>Referent</td>
<td>0.0259</td>
</tr>
<tr>
<td>Multi-tier</td>
<td>22 (56.4)</td>
<td>-22.50</td>
<td></td>
</tr>
<tr>
<td>No. of system levels/tiers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 tier</td>
<td>16 (42.1)</td>
<td>Referent</td>
<td>0.0306</td>
</tr>
<tr>
<td>2 tiers</td>
<td>8 (21.1)</td>
<td>-29.50</td>
<td></td>
</tr>
<tr>
<td>≥ 3 tiers</td>
<td>14 (36.8)</td>
<td>-21.50</td>
<td>0.0601</td>
</tr>
<tr>
<td>Enrichment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>14 (36.8)</td>
<td>Referent</td>
<td>0.0159</td>
</tr>
<tr>
<td>No</td>
<td>24 (63.2)</td>
<td>-25.43</td>
<td></td>
</tr>
<tr>
<td>Floor type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All litter</td>
<td>8 (21.6)</td>
<td>Referent</td>
<td>0.4797</td>
</tr>
<tr>
<td>Combination</td>
<td>21 (56.8)</td>
<td>8.62</td>
<td></td>
</tr>
<tr>
<td>All wire/slatted</td>
<td>8 (21.6)</td>
<td>42.25</td>
<td>0.0063</td>
</tr>
<tr>
<td>Proportion of litter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No litter</td>
<td>8 (22.2)</td>
<td>Referent</td>
<td>0.0117</td>
</tr>
<tr>
<td>≤ 1/3 litter</td>
<td>9 (25.0)</td>
<td>-37.03</td>
<td></td>
</tr>
<tr>
<td>&gt; 1/3 litter</td>
<td>19 (52.8)</td>
<td>-37.47</td>
<td>0.0041</td>
</tr>
<tr>
<td>Variable</td>
<td>Yes</td>
<td>Referent</td>
<td>No</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td><strong>Litter type</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No litter</td>
<td>8 (22.2)</td>
<td>Referent</td>
<td>20 (54.1)</td>
</tr>
<tr>
<td>Sawdust or sand</td>
<td>7 (19.4)</td>
<td>-36.39</td>
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<tr>
<td>Wood shavings or straw</td>
<td>14 (38.9)</td>
<td>-35.11</td>
<td></td>
</tr>
<tr>
<td>Manure</td>
<td>7 (19.4)</td>
<td>-36.39</td>
<td></td>
</tr>
<tr>
<td><strong>Litter replacement</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9 (24.3)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>20 (54.1)</td>
<td>-17.53</td>
<td></td>
</tr>
<tr>
<td>No litter</td>
<td>8 (21.6)</td>
<td>23.92</td>
<td></td>
</tr>
<tr>
<td><strong>Raking of litter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>18 (51.4)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9 (25.7)</td>
<td>-5.78</td>
<td></td>
</tr>
<tr>
<td>No litter</td>
<td>8 (22.9)</td>
<td>34.14</td>
<td></td>
</tr>
<tr>
<td><strong>Farmer visit during rear</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>24 (64.9)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>13 (35.1)</td>
<td>13.91</td>
<td></td>
</tr>
<tr>
<td><strong>Housing type in rear</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-tier</td>
<td>20 (54.0)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>Multi-tier</td>
<td>17 (46.0)</td>
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<td></td>
</tr>
<tr>
<td><strong>Matched perches in rear &amp; lay</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>23 (60.5)</td>
<td>-17.33</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>15 (39.5)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td><strong>Matched litter in rear &amp; lay</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>20 (52.6)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>18 (47.4)</td>
<td>22.97</td>
<td></td>
</tr>
<tr>
<td><strong>Manure belt frequency</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 3x per week</td>
<td>8 (21.6)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>1-2x per week</td>
<td>17 (46.0)</td>
<td>12.35</td>
<td></td>
</tr>
<tr>
<td>End of flock</td>
<td>12 (32.4)</td>
<td>35.83</td>
<td></td>
</tr>
<tr>
<td><strong>Flock health plan in place</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>11 (33.3)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>22 (66.7)</td>
<td>13.73</td>
<td></td>
</tr>
<tr>
<td><strong>No. of diet changes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 1 change</td>
<td>13 (34.2)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>2-3 changes</td>
<td>14 (36.8)</td>
<td>18.31</td>
<td></td>
</tr>
<tr>
<td>≥ 4 changes</td>
<td>11 (29.0)</td>
<td>20.85</td>
<td></td>
</tr>
<tr>
<td><strong>Insoluble grit in diet</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>7 (18.9)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>30 (81.1)</td>
<td>14.29</td>
<td></td>
</tr>
<tr>
<td><strong>Insoluble fibre in diet</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>13 (35.1)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>24 (64.9)</td>
<td>-15.31</td>
<td></td>
</tr>
<tr>
<td><strong>Animal by-product in diet</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>6 (17.6)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>28 (82.4)</td>
<td>29.33</td>
<td></td>
</tr>
</tbody>
</table>
### Table 3.5. Final linear regression model for feather damage prevalence in laying hen flocks housed in non-cage systems ($\alpha = 0.05$, $R^2 = 0.7306$, adjusted $R^2 = 0.6407$, $F_{8,24} = 8.134$, $P<0.001$, $N = 39$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>SE</th>
<th>ANOVA P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-18.28</td>
<td>12.528</td>
<td></td>
</tr>
<tr>
<td>Flock age (centered)</td>
<td>0.91</td>
<td>0.293</td>
<td>0.0017</td>
</tr>
<tr>
<td>Floor type</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>All litter</td>
<td>Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combination</td>
<td>6.50</td>
<td>10.789</td>
<td></td>
</tr>
<tr>
<td>All wire/slatted</td>
<td>37.61</td>
<td>13.065</td>
<td></td>
</tr>
<tr>
<td>Manure belt frequency</td>
<td></td>
<td></td>
<td>0.0151</td>
</tr>
<tr>
<td>&gt;3x per week</td>
<td>Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2x per week</td>
<td>12.95</td>
<td>9.718</td>
<td></td>
</tr>
<tr>
<td>End of flock only</td>
<td>20.13</td>
<td>10.702</td>
<td></td>
</tr>
<tr>
<td>Enrichment</td>
<td></td>
<td></td>
<td>0.0586</td>
</tr>
<tr>
<td>Yes</td>
<td>19.06</td>
<td>8.036</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matching of litter*</td>
<td></td>
<td></td>
<td>0.2058</td>
</tr>
<tr>
<td>Yes</td>
<td>Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>14.09</td>
<td>9.543</td>
<td></td>
</tr>
<tr>
<td>Dawn/Dusk period</td>
<td></td>
<td></td>
<td>0.1086</td>
</tr>
<tr>
<td>Yes</td>
<td>Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>15.00</td>
<td>9.000</td>
<td></td>
</tr>
</tbody>
</table>

*Matching of litter conditions in both rearing and laying periods of flock’s life
Chapter 4: An Investigation of Associations Between Management and Feather Damage in Canadian Laying Hens Housed in Furnished Cages

4.1 Abstract

Feather pecking is a continuous welfare challenge in the housing of egg-laying hens. Canada is currently making the transition from conventional cages to alternative housing systems. However, feather damage (FD) among laying hens due to feather pecking remains a welfare concern, despite increased space allowance and better opportunity to perform natural behaviours. With the goal of improving hen welfare in practice, an explorative approach was taken to assess bird, housing, and management associations with FD in Canadian laying hens housed in alternative systems. A questionnaire, focused on housing and management practices, was designed and administered to 122 laying farms across Canada in autumn of 2017 (response rate of 52.5%), providing information on a subset of 26 flocks kept in furnished cages. Additionally, a three-point feather cover scoring system was developed for farmers to estimate the prevalence of FD present on-farm. Farmers assessed a sample of 50 birds per flock and prevalence of FD was determined. Linear regression modeling was applied to explain FD prevalence as a function of 6 (out of 54 available) variables. Of the 6 modeled variables, “age”, “brown feather colour”, “midnight feeding”, and “no access to a scratch area” were found to be associated with higher levels of FD. The model explains 77% of variation in the FD prevalence at farm level ($R^2=0.77$). The results indicate that FD, as a result of feather pecking, is a multifactorial problem and support existing evidence that FD increases as birds age. These results also suggest that “feather
colour”, “midnight feeding”, and “access to (or lack of) a scratch substrate” play a role in FD prevalence in furnished cages.

**Keywords:** laying hen, feather damage, furnished cage, welfare

### 4.2 Introduction

Today’s egg-laying hens face a multitude of welfare challenges, one of the most prominent being that of feather pecking (FP), which is experienced across all types of modern housing systems (Sherwin, Richards, and Nicol 2010; Lay et al. 2011; Yilmaz Dikmen et al. 2016). FP is a behaviour where hens peck, pull (Willimon and Morgan 1953), or pluck at (Neal 1956), and sometimes eat the feathers of their conspecifics (McKeegan and Savory 1999; Harlander-Matauschek and Bessei 2005), causing feather damage (FD) and feather loss typically on the back/rump, vent, and tail area (Savory 1995; McAdie and Keeling 2000; Glatz 2001). In addition to increased risk of abrasion and infection due to exposed areas of skin, loss of feather cover results in difficulty maintaining body temperature (Tauson et al. 2006), and body balance (LeBlanc et al. 2016), and can lead to mortality due to cannibalism of denuded areas (Savory 1995). FD thus significantly reduces bird welfare as well as increases economic losses for producers due to increased flock mortality and feed consumption, and reduced egg production (Glatz 2001; Johnsen, Vestergaard, and Nørgaard-Nielsen 1998; Yamak and Sarica 2012). The act of FP is considered to be a form of redirected foraging behaviour, where the feathers of other birds become a substrate of interest resulting in FD (Blokhuis 1986; Huber-Eicher and Wechsler 1998). This behaviour is triggered by multiple factors, such as diet composition and rearing period, acting in combination with housing design, environment and bird strain (Nicol et al. 2013).
As of 2017, approximately 77% of Canadian laying hens are housed in conventional cages (EFC 2017). Use of alternative housing systems, such as furnished cages, single-tier floor systems, and multi-tier aviaries, and free-range systems, which allow birds to express more natural behaviours, is, however, becoming more common in egg production (van Staaveren et al. 2018). In Australia, for example, the 2018 market share of free-range eggs by volume has now surpassed that of cage eggs at 45.4% and 44.0%, respectively (Australian Eggs Limited 2018). The European Union even discontinued the use of conventional cages as of 2012 (Department for Environment Food & Rural Affairs 2006). Canada is now following suit by transitioning out of conventional cage housing and into furnished cage and non-cage systems; a goal to be reached by July 1st, 2036 (National Farm Animal Care Council 2017).

Though these housing systems are considered an improvement in bird welfare, FP behaviour and FD outcomes pose a greater risk in these alternative systems where a pecking bird has access to a larger number of pecking victims (Keeling and Jensen 1995). Birds in furnished cages are typically housed in groups of 10 – 100 birds (National Farm Animal Care Council 2017) and >1000 birds in non-cage systems (Lay et al. 2011). In these larger groups, FP can be transmitted through social learning and thus lead to sizeable FP outbreaks (Zeltner, Klein, and Huber-Eicher 2000). With the advent of new housing practices in Canada, identifying which farming factors contribute the most to poor feather cover and subsequently how to prevent and manage it, is especially needed at this time.

Much research has been done to determine influencing factors of FP and to quantify poor plumage condition – primarily in Europe. Both experimental and epidemiological studies, with a focus on non-cage systems, have yielded genetics, stocking density, group size, rearing factors...
(e.g. perching, foraging, and dustbathing opportunities), floor type, feed, and light intensity, as main factors that impact FP behaviour and FD (Bilčík and Keeling 1999; Lambton et al. 2010; Huber-Eicher and Audigé 1999; de Haas et al. 2014; Aerni, El-Lethy, and Wechsler 2000; Gunnarsson, Keeling, and Svedberg 1999; Drake, Donnelly, and Stamp Dawkins 2010). Comparatively little is known about FD and its risk factors in a North American context, especially in furnished cages. Currently, furnished cages are increasingly implemented in Canada as one of the alternative housing systems for laying hens and are seen by egg farmers as a valuable compromise to conventional cages.

The goal of this study is to report on putative risk factors for FD observed in furnished caged flocks in a Canadian setting as part of a larger project. The specific objectives are (i) to identify and quantify associations between FD and reported risk factors in the areas of management, environment, and genetics in laying hen flocks in alternative housing systems, (ii) to provide farmers with the strategies to prevent/control FD in such systems, as well as (iii) to provide the industry with tools to assess and monitor feather cover damage.

4.3 Materials and Methods
This study was part of a larger epidemiological project to investigate FD in laying hens kept in alternative housing systems on Canadian farms (van Staaveren et al. 2018). The study was conducted as per (Chapter 3) which describes results for the non-cage flocks. In brief, egg farmers were asked to 1) assess FD prevalence in their flock using a visual FD scoring system and 2) complete a comprehensive questionnaire based on housing features and management practices. This information was used to 3) identify farm characteristics and practices associated with FD using regression modelling.
4.3.1 Development of the Feather Damage Scoring System

FD was assessed by farmers using a visual scoring system, which had been specifically designed for this project (Chapter 2). Here, FD encompasses both the destruction of feathers and their loss. The system involved a three-point scale from 0 to 2 according to severity (Table 4.1) to allow scoring of both extremes of good and poor feather cover along with a more intermediate feather cover. A visual assessment of the back/rump area was used to prioritize user-friendliness and time efficiency as it has been previously validated compared to capture and handling (Bright, Jones, and Dawkins 2006; Giersberg, Spindler, and Kemper 2017). Additionally, FP is typically targeted at the back/rump area and it is less likely that damage in this area is caused by other conditions, such as abrasion from the system (Bilčík and Keeling 1999; Nicol et al. 2013).

Farmers were asked to sample 50 birds selected evenly across all sections of the barn (University of Bristol 2013; de Haas et al. 2014; Heerkens et al. 2015). Detailed instructions with schematics to illustrate how to select birds, a feather cover scoring guide with full colour photographs of the scoring scales for white and brown birds, and recording sheets were provided.

4.3.2 Development of the Layer Questionnaire

A questionnaire for laying hen farmers was adapted from Lambton et al. (2013) which similarly looked at FP in laying hens in alternative systems and its associations with management and environmental factors. The questionnaire was adapted to comprise primarily housing and management-based questions specific to current Canadian practices and standards (National Farm Animal Care Council 2017), using the expertise of the research team and feedback from federal and provincial egg boards. The main subsections of the questionnaire are outlined in Table 4.2. The questionnaire consisted of open-ended and closed questions with multiple answer
options, and versions in both English and French were available. Both the questionnaire and the scoring instructions were pilot tested at Arkell Poultry Research Station (University of Guelph) as well as local farms representing alternative systems.

4.3.3 Questionnaire Distribution

In order to reach as many egg farmers as possible, questionnaires were provided to participants in both hard copy form via mail-out, and electronically via Qualtrics® online survey software (Qualtrics 2017). Questionnaire distribution was coordinated through the egg boards within each province to help maintain participant privacy using unique numeric codes on all documents. Documents included in the package were: (1) a laying hen questionnaire, (2) a feather cover damage scoring guide, (3) two feather cover damage scoring sheets – one for white hens and one for brown hens, (4) a cover letter outlining the study with a consent form, and (5) a return-addressed envelope for the return of written responses.

Distribution of the survey began on October 3, 2017, and data was collected through to December 31, 2017. Reminders were sent out by the provincial egg boards 2-4 weeks post initial distribution and once more two weeks before data collection ceased. This study was approved by the University of Guelph Research Ethics Board (REB17-06-010).

4.4 Statistical Methods

FD prevalence was estimated as the percentage of sampled birds with back scores of 1 or 2 on each farm. The data obtained from the farmer questionnaires was used to determine factors associated with the prevalence of FD within a flock. All statistical analyses were performed using R version 3.4.3 “Kite-Eating Tree” (R Core Team 2017) in combination with RStudio (RStudio Team 2016).
4.4.1 Model building

Data collected via the questionnaire was entered using double manual entry and checked for errors. Variables with excessive missing values (> 50% of responses missing) or with insufficient variation (e.g. a binary variable with a proportion of responses approximately > 0.85) were excluded from further investigation. Response categories for several variables underwent retrospective collapsing to remove unused and infrequent categories. Linearity of continuous variables was checked. After this screening, a total of 54 variables remained and were included in univariable analysis. Variables with some evidence of association to the outcome in a univariable analysis, i.e. reached the criterion of P ≤ 0.25, or were considered biologically relevant, were retained for further investigation. Spearman rank-correlations were estimated for continuous variables and Pearson’s chi-squared tests performed for categorical variables to test for collinearity and unduly strong association between predictor variables. Finally, 24 remaining predictor variables for FD prevalence were included in multivariable analysis using a mixed linear regression model with a forward variable selection approach. Variables that were significant (P ≤ 0.05) and/or contributed to a high adjusted R² comprised the final model. Relevant interactions between retained predictor variables were tested. The variable for flock age was centered at 40 weeks in an effort to allow for a more intuitive interpretation of FD prevalence at this age.

4.4.2 Diagnostic Procedures

Model diagnostics were carried out to assess normality of residuals using a QQ-plot (Dohoo, Martin, and Stryhn 2009). Homogeneity of variance was also evaluated graphically with a scatterplot of standardized residuals against fitted values. Collinearity was assessed using the
Variance Inflation Factor (VIF). The presence of outliers was checked using a boxplot of model residuals, and the absence of influential data points was checked using Cook’s distance.

4.5 Results

4.5.1 Response Rate

As a part of a larger cross-sectional study, a total of 122 questionnaire packages were distributed to laying hen farms where birds were not housed in conventional cages (van Staaveren et al. 2018). The number of packages returned totalled 64 (response rate of 52.5%), providing information for 65 flocks of which 26 flocks were housed in furnished cages (40.0%).

4.5.2 General Flock Information

Flock size, flock age in weeks, and FD prevalence for these flocks are presented in Table 4.3. Birds in all flocks were beak-trimmed at the hatchery (day 1) with an infrared laser. Most flocks had white-feathered birds (76.9%), while 23.1% of flocks were brown-feathered. Twenty-three farmers provided information on the breed of their flock showing that almost half (43.5%) were of Lohmann breed, while others included Bovans (4.3%), Dekalb (34.8%), Hy-line (4.3%), and ISA (13.0%). A detailed description of study flocks and housing and management practices on these farms is presented in van Staaveren et al. 2018.

4.5.3 Univariable Analysis of Factors in Furnished Cages

Housing and management factors associated (P ≤ 0.25) with FD in furnished cage systems at the univariable level of analysis included the following: amount of farmer experience in years, age of the flock in weeks, stocking density defined as the number of hens per cage, feather colour, bird condition on arrival at the laying facility, inspection route, frequency of feeder running, and whether midnight feeding was used (Table 4.4).
While the following variables did not meet the inclusion criterion of $P \leq 0.25$, they were retained for multivariable model building due to their previously established connections with feather cover condition and/or their biological importance. These variables included: cage space allowance, provision of a scratch area and scratch substrate, rearing factors such as flock origin (same flock or multiple combined) and matching of barn conditions, length of daily inspections, use of a health plan, feed-related factors such as feed structure, diet changes, and provision of insoluble fibre, light type and intensity, and frequency of manure belt running (Table 4.4).

### 4.5.4 Linear Regression Analysis for Furnished Cage Flocks

The final linear regression model included six variables: “flock age (weeks)”, “feather colour”, “feed structure”, “frequency of feeder running”, “midnight feeding”, and “scratch substrate”. These factors accounted for approximately 77% of the variation in FD between flocks. Increasing “age”, brown “feather colour”, and “midnight feeding”, were found to be associated with higher levels of FD. “Frequency of feeder running” and no “scratch substrate” had a tendency of association with higher FD, while “mashed feed structure” was not found to be associated with FD, though did contribute to better explain the variation in FD between flocks (Table 4.5).

### 4.6 Discussion

This study sought to assess associations between management, environmental, and genetic factors and FD outcomes in laying hen flocks housed in furnished cage systems in Canada. Findings indicate that on average, approximately 22% (95% CI: 10.4-33.4%) of the birds within these flocks exhibit some form of FD, either moderate or severe. The factors found to have an influence on FD in Canadian flocks included older “age”, use of “brown-feathered birds”, and
abnormal lighting cycle through “midnight feeding practices”. Lack of “scratch substrate” and “frequency of feeder running” tended to be associated with increased FD.

Commentary on how the prevalence of FD found in the current study compares to the existing literature is somewhat difficult since little large-scale epidemiological investigation of FD has been done in commercial furnished cage flocks. Additionally, many studies in which plumage condition is assessed in such flocks report findings only in terms of mortality figures or average feather scores, rather than proportion of the flock affected, as reported here. Of the studies that have reported the proportion of FD, Sherwin et al. (2010) found that after comparison of 4 different UK housing systems, 24.9% of birds were affected by FD after scores were recorded at 30 and 70 weeks of age among 6 furnished cage flocks. Elson and Croxall (2006), who similarly compared welfare between cage and non-cage systems in European flocks, found that all furnished cage flocks in the study had less than 25% of birds with naked back areas at 35 weeks of age, but by 60 weeks some flocks in large group furnished cages had percentages that exceeded 25%. The finding of 21.9% of birds with moderate to severe FD up to approximately 44 weeks of age in the current study is generally in line with those of the previous studies. It is likely, however, that the prevalence here is underestimated due to the wide age range of participating flocks where young flocks newly brought into lay may skew toward a lower prevalence if FP has not yet become apparent. FP behaviour and resultant FD have consistently been shown to increase as birds age (Bilčík and Keeling 1999; Huber-Eicher and Sebő 2001; Lambton et al. 2013), a finding corroborated here with the small but highly significant positive association between FD and age (+0.71% increase in FP per week of age, P <0.001). Had the flocks of the current study been sampled at a uniform middle to late age like the previously
mentioned studies, when FD would be apparent in at-risk flocks, prevalence may have been even higher.

The greatest magnitude of effect on FD found in the present study’s furnished caged flocks was that of feather colour (P = 0.0017). Specifically, flocks with brown-feathered birds predicted 35% more FD than that would be found in white-feathered flocks. This finding is considered here as an indicator of genetic differences between breeds and/or strains. As specific breed information was not always provided by respondents, there was not enough data to reliably assess impact of breed as its own variable. Feather colour was instead used as a close proxy. The literature provides some conflicting evidence as to whether FD occurs more often in brown- or white-feathered birds. De Haas et al. (2014) found that FD was found on more body areas and more injurious pecking behaviour occurred in ISA Brown hens compared to Dekalb White. Similarly, Yamak and Sarica (2012) observed significantly less plumage deterioration in white layers compared to brown. Contrastingly, White Leghorn birds exhibited more fearfulness (a factor involved in FP behaviour (Jones, Blokhuis, and Beuving 1995; Rodenburg et al. 2004) and FD than Rhode Island Red birds in a study by Uitdehaag et al. (2008). These findings were, however, from studies using non-cage systems and battery cages, therefore may not directly apply to furnished cage flocks.

An alternative explanation for the marked difference in observed plumage condition between feather colour in this study could be simply that of observer bias. Brown birds tend to have an under-layer of white feathers that become more visible as the brown top layer is removed or get damaged. Thus FD, in general, may be more easily observed or perceived as damage from afar by a scorer for brown birds compared to white birds. This colour pattern may also affect birds’
own perception of an attractive pecking substrate as they have been shown to feather peck in response to contrast of light and dark, such as that found by Keeling et al. (2004), where white birds with brown pigmentation were more vulnerable to FP than all-white birds, and by Bright (2007) who found that Oakham Blue birds with white plumage had less FD due to FP than black or grey birds. Interestingly in the study by McAdie and Keeling (2000), which looked at the effect of feather manipulation on FP and cannibalism in brown birds, it was found that damaged feathers received significantly more severe feather pecks than undamaged feathers. Their feather manipulations through trimming revealed the feathers’ light-colored bases, also suggesting that color contrast could play a role in damaged feathers being an attractive FP stimulus in brown birds.

The practice of midnight feeding, where the dark phase of the lighting cycle is interrupted for a period of 1-2 hours to encourage hens to eat at this time, is used to either promote general growth or as a way for birds to take in more calcium for egg formation (European Food Safety Authority 2005). This practice was found to have a strong, positive association with FD in furnished cage flocks (P = 0.0232), estimating an increase in FD by 24%. This practice is no longer allowed in Europe (European Commission 1999), but is still in use in North America and is viewed positively from a production standpoint, especially for use in summer months or hot climates (Grizzle et al. 1992). Midnight feeding has not been well-explored from a welfare perspective and thus little is known regarding its possible negative effects on bird behaviour. In humans, however, the literature surrounding night shift and rotating shift work’s disruption of circadian rhythms suggests a negative impact on health. Numerous studies, especially in healthcare and hospital workers, have documented negative effects on mental health and behaviour such as increased symptoms of anxiety and depression (Kalmbach et al. 2015; Bjorvatn et al. 2012), and
increased irritability, tension, and anger (Saadat et al. 2016). It may be suggested that the added burden of interrupted sleep could exacerbate existing behavioural problems in hens and thus may be a plausible contributor to poor plumage condition.

It is also worth considering that midnight feeding may contribute to FD in one other aspect: more time awake may simply mean more opportunity for FP to take place among active birds. Less time at rest during the dark phase would result in less time in which FP victims can escape peckers and recuperate, thus potentially leading to a greater amount of observed FD compared to flocks with undisturbed rest for a full 8 hours. This makes sense considering what is known about the use of dark brooders for rearing chicks. Dark brooders, which are curtained, box-like structures that provide conductive heat, allow birds to rest and stay warm in a dark environment, thus simulating the role of a brooding hen (Gilani, Knowles, and Nicol 2012). Farms that do not use dark brooders, but rather use whole house heaters, typically leave chicks exposed to continuous light in their early days of life (Gilani, Knowles, and Nicol 2012). Research, both experimentally (Jensen, Palme, and Forkman 2006) and on commercial farms (Gilani, Knowles, and Nicol 2012), has determined that the use of dark brooders reduces FP during rearing and into lay. It is believed that dark brooders separate active and inactive chicks, thus allowing birds to rest undisturbed and avoid pecking from active birds.

Lastly, having no scratch substrate present in furnished cages tended to be associated with FD (P = 0.0987). The largest effect was contributed by having no scratch area present in the cage at all, estimating an increase in FD of approximately 18% compared to flocks with access to a scratch area with substrate present. A scratch area, typically a plastic mat that may or may not be textured, allows birds to simulate foraging and dustbathing behaviours. This result is in
accordance with much of the existing literature, as the importance of opportunities for foraging and dustbathing in FP prevention and good plumage condition has been well-documented (Huber-Eicher and Wechsler 1997; Johnsen, Vestergaard, and Nørgaard-Nielsen 1998; Nicol et al. 2001; Gilani, Knowles, and Nicol 2013). Research suggests the additional provision of substrate improves the body integrity and plumage coverage of hens (Huneau-Salaün, Guinebretière, and Michel 2014). One possible reason why lack of provided substrate did not have a stronger effect may be that excreta accumulation on the scratch pads functioned as a reasonable foraging substrate. In an experimental investigation of laying hen behaviour in response to clean versus excreta-covered scratch pads, Pokharel et al. (2018) demonstrated that hens displayed a preference for foraging on pads covered in excreta and visited them more frequently over the clean option. Additionally, hens have been found to voluntarily consume the excreta of other hens even in the presence of an excreta-free feed source, suggesting a role for excreta as foraging material (von Waldburg-Zeil, van Staaveren, and Harlander-Matauschek 2018) if no appropriate foraging material is available. This finding in the current study may alternatively be an indicator that the presence of a scratch area at all is what makes the largest difference in amount of FD, more than that of additional litter in a furnished cage environment. More likely, the sample of flocks that had access to substrate was not large enough to detect a significant difference between groups.

Though frequency of feeder running tended to be associated with higher FD, the magnitude of effect was very small and its impact does not have a clear explanation at this time. Therefore, this factor was not further considered.
It is important to note that this was an exploratory study, and thus the p-values exhibited should be considered exploratory p-values (Spiegelhalter 2017). Additionally, no age restriction was imposed on participating flocks. Therefore, the factors investigated here may not have yet reflected their impact on plumage condition at the time of feather cover assessment for young flocks.

4.7 Conclusions

For the first time in Canada, this study estimated the prevalence of FD on farms housing laying hens in furnished cages, revealing that on average, 22% of birds display moderate or severe FD due to FP. It is evident that FD currently poses a problem for Canadian farmers and for those transitioning into furnished cage housing in the coming years. The findings here suggest that providing birds with the opportunity to forage using scratch areas in cages continues to be an important element in preventing FD in laying flocks, that midnight feeding practices may induce FP stress, and that brown birds may be more at risk for FD in furnished cage housing. The value of undisturbed rest for hens should not be underestimated and should be studied further in North American settings, as well as whether white or brown-feathered birds are more suited to furnished cage housing.

Much research has been done in exclusively non-cage, free-range, and/or organic flocks in Europe and Australia. Comparisons of those findings to those found in the present study are not always directly applicable due to differences in production and management methods. Consequently, further investigation into furnished cage management impacts on FD is needed under commercial conditions and in diverse regions.
REFERENCES


TABLES

Table 4.1. The scoring system used by farmers on-site to evaluate the feather condition and amount of feather damage present in their flock. Body areas scored were limited to the back/rump.

<table>
<thead>
<tr>
<th>Score</th>
<th>Body condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Intact feather cover, no or slight wear, only single feathers missing</td>
</tr>
<tr>
<td>1</td>
<td>Damaged feathers (worn/deformed) or bald patch visible ≤ a $2 coin</td>
</tr>
<tr>
<td>2</td>
<td>At least one bald patch visible that is &gt; a $2 coin</td>
</tr>
</tbody>
</table>

Table 4.2. A summary of the housing and management information about a farmer’s current laying hen flock collected through the self-administered questionnaire.

<table>
<thead>
<tr>
<th>General Information</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>Years of farming experience</td>
<td></td>
</tr>
<tr>
<td>Province</td>
<td></td>
</tr>
<tr>
<td>Farm size</td>
<td></td>
</tr>
</tbody>
</table>

| Flock Information                    |                                                                                     |
| Hatchery & rearing farm birds came from |                                                                                     |
| Date of placement                    |                                                                                     |
| Age of placement                     |                                                                                     |
| Current flock age                     |                                                                                     |
| Flock size at placement & current size|                                                                                     |

| Housing Features                     |                                                                                     |
| No. of cage tiers and rows           |                                                                                     |
| Manufacturer & model                 |                                                                                     |
| Age of system                        |                                                                                     |
| Stocking density                     |                                                                                     |
| Perches (availability, height, space) |                                                                                     |
| Cage scratch area (availability, type, foraging material, cleaning) |                                                                                     |
| Nests (availability, type, location) |                                                                                     |
| Drinker & feeder type                |                                                                                     |
| Enrichment (types, age of access, motivation for use) |                                                                                     |

<p>| Bird Characteristics                  |                                                                                     |
| Feather colour                        |                                                                                     |
| Breed                                 |                                                                                     |</p>
<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Rearing and Placement** | Visitation of pullet flock  
Home-rearing vs. supplier, integration of flocks yes/no  
Pullet housing system  
Beak trimming (yes/no, age, method, length)  
Condition on arrival  
Matching of environmental conditions |
| **Flock Health**       | Inspection (frequency, duration, no. of workers, route, observations)  
Feather pecking (if it had been observed, body area, at what age, any management changes in response)  
Flock behaviour in response to workers  
Biosecurity measures  
Vaccination & instances of illness  
Mortality (percentage & main causes) |
| **Diet**               | Feed structure, supplier, availability, supplements  
Feeding frequency & special practices (midnight feeding)  
Diet changes  
System breakdowns |
| **Lighting**           | Type, hours of light, intensity  
Dawn/dusk period (yes/no) & method |
| **Air quality**        | Type of ventilation  
Temperature, humidity, ammonia concentration, dust levels  
Manure removal frequency |
| **Productivity**       | Age at start of lay  
No. of eggs collected per day, percentage of floor eggs  
Performance compared to breed standards  
Current & peak production figures |
Table 4.3. Description of 26 laying hen flocks housed in furnished cages by average age, flock size and prevalence of feather damage (FD).

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean (SD)</th>
<th>Median (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flock age (wks)</td>
<td>26</td>
<td>43.6 (15.77)</td>
<td>43.5 (21-69)</td>
</tr>
<tr>
<td>Flock size</td>
<td>26</td>
<td>15212 (9587.6)</td>
<td>13006.0 (43710-47721)</td>
</tr>
<tr>
<td>FD prevalence (%)</td>
<td>1300*</td>
<td>21.9 (28.44)</td>
<td>6.0 (0-94)</td>
</tr>
</tbody>
</table>

*Total number of birds scored for FD (26 x 50)

Table 4.4. Housing and management factors (P ≤ 0.25) associated with the presence of feather damage in furnished cage laying flocks at the univariable analysis level.

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>N (%)</th>
<th>Coefficient</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer experience</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 10 years</td>
<td>12 (46.2)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>More than 10 years</td>
<td>14 (53.8)</td>
<td>-15.31</td>
<td>0.1762</td>
</tr>
<tr>
<td>Flock age (weeks)</td>
<td>26 (100.0)</td>
<td>1.09</td>
<td>0.0010</td>
</tr>
<tr>
<td>Birds all from same rearing flock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>21 (80.8)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>5 (19.2)</td>
<td>-7.33</td>
<td>0.6145</td>
</tr>
<tr>
<td>Feather colour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>20 (76.9)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>Brown</td>
<td>6 (23.1)</td>
<td>36.50</td>
<td>0.0035</td>
</tr>
<tr>
<td>No. of hens/cage</td>
<td>26 (100.0)</td>
<td>0.40</td>
<td>0.1204</td>
</tr>
<tr>
<td>Cage space allowance (cm²)</td>
<td>26 (100.0)</td>
<td>0.04</td>
<td>0.4319</td>
</tr>
<tr>
<td>Scratch area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>14 (53.8)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>12 (46.2)</td>
<td>0.76</td>
<td>0.9474</td>
</tr>
<tr>
<td>Scratch Substrate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>8 (30.8)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>6 (23.1)</td>
<td>1.92</td>
<td>0.9057</td>
</tr>
<tr>
<td>No scratch area</td>
<td>12 (46.2)</td>
<td>1.58</td>
<td>0.9079</td>
</tr>
<tr>
<td>Matched housing type*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>3 (11.5)</td>
<td>Referent</td>
<td></td>
</tr>
<tr>
<td>No</td>
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<td>P-value</td>
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<td>Matching of conditions*</td>
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<td>0.2810</td>
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<td>1x per week</td>
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<td>≤ 10 lux</td>
<td>11 (55.0)</td>
<td>Referent</td>
<td>0.6769</td>
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<tr>
<td>&gt; 10 lux</td>
<td>9 (45.0)</td>
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<td>≤ 1 change</td>
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<td>4 (15.4)</td>
<td>Referent</td>
<td>0.0771</td>
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<td>No</td>
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<td>≥ 45 mins</td>
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<td>Injury/illness on arrival at laying barn</td>
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<td>4 (15.4)</td>
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<td>No</td>
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+Housing system type in which birds were kept during rear was the same used during lay

*Whether conditions in the laying barn match those in which birds were kept during rear in terms of litter and perch availability, nutrition measures, and environmental aspects such as light and temperature

**Table 4.5.** Linear regression model of factors associated with feather damage prevalence in laying hen flocks housed in furnished cages (α = 0.05, R² = 0.768, adjusted R² = 0.678, F7,18 = 8.513, p<0.001, N = 26).

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<td>Flock age (centered at 40w)</td>
<td>0.71</td>
<td>0.228</td>
<td>&lt;0.001</td>
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<td>Feather colour</td>
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<td>White</td>
<td>34.60</td>
<td>9.039</td>
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<tr>
<td>Brown</td>
<td>Referent</td>
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<tr>
<td>Feeder running frequency</td>
<td>2.45</td>
<td>1.540</td>
<td>0.0522</td>
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<td>Midnight feeding</td>
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<td>Yes</td>
<td>24.39</td>
<td>9.202</td>
<td>0.0232</td>
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<td>Referent</td>
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<tr>
<td>Feed Structure</td>
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<td></td>
<td></td>
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<tr>
<td>Mash</td>
<td>13.20</td>
<td>7.697</td>
<td>0.1872</td>
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<tr>
<td>Pellets, grains or crumbs</td>
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<td>No</td>
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<tr>
<td>No scratch area</td>
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<td>7.878</td>
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Chapter 5: Discussion, Limitations, Future Directions, Conclusions

5.1 Discussion

Canada’s egg farming transition (away from conventional cage housing and into alternative systems) necessitates better understanding of factors that influence the occurrence of FD in commercial laying hen flocks. No nationwide study providing comprehensive assessment of FD has been previously undertaken in Canada. The goal of this thesis was, therefore, to identify and quantify associations between FD and reported risk factors regarding the management, environment, and genetics of laying hens. This was achieved through the development of a simplified, Canadian-tailored FD scoring system, and a survey of farms using a questionnaire focused on housing and management practices.

Moderate to severe FD was estimated at 21.9% (95% CI: 10.4-33.4%) across 26 furnished cage systems and 25.9% (95% CI: 15.6-36.2%) across 39 non-cage systems comprised of single-tier floor systems and multi-tier aviaries. Presence of FD at these levels does indicate a current welfare issue for Canadian hens. However, these estimates are substantially lower than those previously reported for flocks investigated throughout Europe (Gunnarsson, Keeling, and Svedberg 1999; Bestman and Wagenaar 2003; de Haas et al. 2014). Reasons for this variance may be attributed to differences in scoring methods, breeds involved, age at assessment, and routine practice of de-beaking in North America compared to the banning of de-beaking in Europe. Additionally, the data collected here did not provide enough evidence for a statistical difference in FD prevalence at flock level between non-cage and furnished cage housing systems using Fisher’s exact test with a 5% significance level. This lack of difference might be attributed
to two factors: (a) the small sample sizes of both groups, and (b) a difference in the flock age
distribution, which is not adjusted for in Fisher’s exact test.

A prominent finding in this thesis was the association between variables related to foraging
opportunity and FD (i.e., lack of foraging opportunity was associated with increased FD).
Factors with a large magnitude of effect on FD included floor type of non-cage systems (an
indicator of litter availability) and provision of scratch substrate for furnished cage systems. This
is in keeping with other epidemiological studies where the absence of litter substrate increased
FP activity and resulted in poorer plumage condition in non-cage systems (Green et al. 2000;
Lambton et al. 2010) and in experimental studies with birds housed in furnished cages (Huneau-
Salaïn, Guinebretière, and Michel 2014). Related to foraging opportunity was the factor of
enrichment provision, which surprisingly had the tendency of association with increased FP in
non-cage systems. This is opposite to what is expected considering the findings of previous
research where enrichment with objects such as pecking blocks, strings, and bales of hay
prevented or reduced the occurrence of FP and FD in chicks (McAdie et al. 2005; Zepp et al.
2018). This opposite effect could be an indicator that enrichment is most beneficial during
rearing rather than in lay, or that farms with existing or recurring problems with FP behaviour
are those that often supply enrichment as a control measure.

In non-cage systems, an additional association was found between frequency of manure removal
and increased FD, with the largest contribution to this effect coming from farms where manure
was removed only at the end of the laying period. As a likely indirect indicator of reduced air
quality due to higher ammonia levels, this finding corresponds with the link between high
ammonia and poor plumage condition found by previous epidemiological research (Drake, Donnelly, and Dawkins 2010).

Lastly, in furnished cage systems, both the practice of midnight feeding and the keeping of brown-feathered birds had an association with increased FD in these flocks. The effect of midnight feeding, though not previously well explored as a potential risk factor, aligns well with the known associations between abnormal lighting cycle and behavioural problems in chicks (Gilani, Knowles, and Nicol 2012), and in humans (Saadat et al. 2016). With regards to brown-feathered flocks being associated with greater plumage damage, this finding fits well with the studies by McAdie and Keeling (2000) and Keeling et al. (2004), where it was suggested that feather colour contrast created by the presence of dark and light feathers provides an attractive FP stimulus.

### 5.2 Study Limitations

The primary limitation of this study is that since a cross-sectional approach was taken, only a snapshot in time of plumage quality could be obtained. Therefore, this thesis can only discuss associations between FD, management, and housing factors, rather than definitive risk factors, as the development of FD over time in relation to these factors was not investigated. As such, this was an exploratory study. Therefore, p-values should be interpreted with some caution. Furthermore, due to the use of a cross-sectional approach, the flocks captured in this study varied by weeks of age. The timing of flock turnover differs by farm i.e. not all farms in Canada depopulate and repopulate their farms at the same time in a calendar year. Data was collected for each flock at one point in time. Thus, there was a proportion of flocks that likely did not show the outcome of FD at the time of scoring simply because they were young enough that
FD had not yet become apparent. This is likely to have led to an underestimation of FD in Canadian flocks.

It is also important to note that despite best efforts to make the FD scoring system as simple and reliable as possible through testing among the research team, farmers were ultimately responsible for scoring their own birds and so were not trained in the scoring system beforehand. A FD scoring guide was therefore developed to ensure good understanding of the scoring procedure by farmers to the best of the researchers’ ability. However, inter-observer reliability among the participants could not be assessed and could potentially be lower than that determined within the research team. Time and travel limitations prevented the data from being collected in-person by the researchers, which, if done, may have ensured greater reliability of FD scores.

Lastly, like all survey-based investigations, the data collected here may be subject to participation and reporting biases. As the questionnaire was administered from a distance, farmers were solely responsible for supplying the requested information. Additionally, as survey response was dependent on which farms were willing to participate, those who accepted and completed a questionnaire package may possess a set of characteristics different from those of the rest of the target population. This subsequently may only give a partial look at the reality of FP in Canada.

5.3 Future Directions

Future studies would benefit from a longitudinal design as this would allow for the establishment of a temporal component and thus a stronger causal link between FD and factors of interest. A longitudinal approach would additionally allow the investigation of the impact of rearing factors
on FD later in life if birds were followed from hatch to mid-lay, the time at which FD would be apparent if FP was occurring. A longitudinal study would, however, be very time intensive and thus require extensive coordination between provinces and participating farms. These were such factors that posed challenges while designing the current study and which prompted the decision to take a cross-sectional approach.

For future studies that employ cross-sectional methodology for FD assessment, response rate may be increased by simply allowing for a longer span of time for collection of survey responses. Additionally, limiting an investigation to a specific geographical area, such as by province, may allow for greater recruitment efforts to boost participation. This may also allow FD scoring and questionnaire response collection to be performed by trained members of the research team, thus increasing the reliability of obtained information. Regarding questionnaire length, future studies would further benefit from a more targeted approach with a focus on a smaller, specific set of factors of interest.

In the context of the factors discussed here, intervention studies whereby management strategies are employed and evaluated for their ability to reduce FD outcomes are needed going forward.

5.4 Conclusions
This thesis serves as a valuable first step in understanding FD in Canada regarding both prevalence and possible influential factors. FD was found to be present in Canadian flocks, and at levels that suggest a welfare problem for hens housed in alternative systems. It can be concluded that foraging opportunity continues to be an important component of FD occurrence, with the suggestion that factors of air quality, lighting cycle, and strain differences are also
influential. Based on the findings presented, farmers may benefit from prioritizing litter availability for foraging, being diligent in the maintenance of good air quality, and abstaining from the use of abnormal lighting cycles such as midnight feeding, that may infringe upon birds’ ability to rest and escape aggressors. The research presented here will help facilitate the regular monitoring of FD on farms, as well as inform future hypothesis-testing studies to develop improved control strategies for FD reduction and welfare improvement of Canadian laying hens.
REFERENCES


FEATHER COVER SCORING GUIDE

What to score

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<thead>
<tr>
<th>Score</th>
<th>Description</th>
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</thead>
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<tr>
<td>0</td>
<td>Intact feather cover, no or slight wear, only single feathers lacking</td>
</tr>
<tr>
<td>1</td>
<td>Damaged feathers (worn, deformed) or bald patch visible that is equal to or smaller than a two-dollar coin</td>
</tr>
<tr>
<td>2</td>
<td>At least one bald patch visible that is larger than a two-dollar coin</td>
</tr>
</tbody>
</table>

DO’s
- Have one person do all scoring
- Assess head/neck and back/rump
- Score 50 random birds

DON’T’s
- Handle the birds (not needed)
- Favour a certain type of bird

Score 0

≤ (Smaller than/equal to)

Score 1

Score 2

> (Larger than)
Back score 0
Neck score 0

Back score 1
Neck score 1

Back score 2
Neck score 2
Where to score your birds

Enriched housing

Cage rows

Select birds from cages in different tiers and different locations (beginning, middle and end of corridors) throughout the house.

Single tier system

The number of birds chosen should be proportional to the number of birds present in each area (litter area, slatted area, nest area, perches). Because 2x as many birds are present on the litter and slatted area, 2x as many birds are selected from these areas compared to the perches and nest area.

Multi-tier system

The number of birds chosen should be proportional to the number of birds present in each area (litter area, slatted area, nest area, perches and the different tiers). The majority of the birds are on the tiers and so a larger number of birds is selected from there than the litter area. At the same time, care is taken to select birds from the different tiers.
FEATHER COVER - SCORING SHEET

Date (dd/mm/yyyy): 
Observer: 
Age of birds (wks): 

Please select
Enriched cage / Single level system (e.g. free run) / Multi level system (e.g. aviary)

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