INJURIOUS PECKING BEHAVIOR OF PEKIN DUCKS ON COMMERCIAL FARMS: CHARACTERISTICS, DEVELOPMENT AND DUCK WELFARE

by

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Dedicated to my parents for their endless love, support and encouragement

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ABSTRACT

Injurious pecking is one of the major welfare concerns for poultry and other captive birds. Injurious pecking behavior can result in welfare problems including feather and skin damage, pain, substantial heat loss because of feather loss, and even death of the recipient bird. Injurious pecking can also cause economic losses because of reduced production efficiency, increased mortality and reduced feed conversion ratio. Injurious pecking behavior includes feather pecking, feather picking, cannibalism and aggressive pecking. Feather pecking, when a bird uses its beak or bill to peck at the feathers of another bird, can be categorized as either gentle feather pecking (repeated and light pecks) or severe feather pecking (singular and hard pecks). Feather picking is described as a self-damaging behavior that occurs in psittacine species such as parrots and also in ducks. Cannibalism is classified as either tissue pecking (persistently forceful pecks directed at exposed skin) or vent pecking (pecks directed at the top of cloaca or below the cloaca). Unlike feather pecking, feather picking and cannibalism, which are not associated with aggression, aggressive pecking establishes and maintains the dominance hierarchy. Limited studies have examined injurious pecking of Pekin ducks, but results from previous research examining duck picking behavior and feather quality suggested that ducks pick mostly at themselves and that the development of picking is related to feather growth and worsens with age. Scant information is available regarding the prevalence of injurious pecking behavior and characteristics of the behavior.

To address some of the gaps in the knowledge regarding injurious pecking behavior of ducks, this study examined 1) age-related changes in frequencies and durations of preening behavior and injurious pecking behavior of Pekin ducks, including self-picking and feather pecking; 2) the body locations most frequently affected, and whether feather removal and feather eating occurred concurrently with injurious pecking; 3) the prevalence of injurious pecking behavior; and 4) age-related changes in duck welfare that may be associated with injurious pecking. Information about preening behavior was recorded because injurious pecking and preening behavior may have similar age-related patterns, as previous studies have suggested that increased levels of preening behavior are related to feather growth.

Data were collected on 5 commercial duck flocks on 5 farms. Welfare data were collected from all 5 flocks and behavior data were collected from 2 of the 5 flocks. For the two flocks, duck behavior was video-recorded over two consecutive days at 20-22d (Period 1), 27-29 d (Period 2),

and 34-36 d (Period 3). Scan sampling and focal animal sampling were used to analyze the video recordings and determine the frequencies and durations of injurious pecking behavior (gentle feather pecking, severe feather pecking, self-picking and aggressive pecking). For scan sampling, the percentage of ducks performing injurious pecking behavior were recorded every 30 min from 0900h to 1500h. For both scan and focal animal sampling, the viewing area of each camera installed in the barn was divided into eight equal squares (observation areas), of which four were randomly selected for analysis. For focal animal sampling, one duck was randomly selected from each observation area and observed for 30 min from 0945h to 1015h and 1345h to 1415h ((n=8 ducks per camera (4 ducks in the morning and 4 ducks in the afternoon) and n=24 ducks per barn)) to determine the duration and frequency of injurious pecking behavior and preening behavior. For all five flocks, duck welfare (feather quality, feather cleanliness, nostril cleanliness, eye condition, footpad condition and gait) was assessed in 100 ducks from each flock between 17-18 d (Period 1), 29-30 d (Period 2), and 36-37 d (Period 3). Welfare data and frequencies of behaviors from focal animal sampling were analyzed using the GLIMMIX procedure (SAS 9.4). Scan animal sampling data and behavioral durations from focal animal sampling data were analyzed using the MIXED procedure (SAS 9.4).

The most frequently observed form of injurious pecking behavior was gentle feather pecking, which increased from Period 1 to Period 2 ($P < 0.001$), then declined from Period 2 to Period 3 ($P < 0.001$). Gentle feather pecking was most frequently directed at the tail, wings and back. Removal of feathers was observed 13 times, and feathers were eaten 7 times in the 6 days of video observation. Ducks' eye condition, feather cleanliness under the tail, and feather quality on all the assessed body locations, except for the neck, worsened with age. Age was a major factor affecting the development of injurious pecking behavior including the proportion of ducks performing gentle feather pecking behavior ($P < 0.001$), frequency and duration of gentle feather pecking behavior (frequency: $P < 0.001$; duration: $P < 0.001$), and other injurious pecking behavior (frequency: $P = 0.038$; duration: $P = 0.036$). From scan sampling, 1.85% of the ducks were observed performing severe feather pecking behavior, 6.84% of the ducks were observed performing aggressive pecking behavior, and no duck was observed performing self-picking behavior in the total of 1082 ducks performing injurious pecking behavior across the 3 periods. From focal sampling, 83.33% of the ducks were observed performing gentle feather pecking behavior, 13.89% of the ducks were observed performing severe feather pecking behavior, 16.67%

of the ducks were observed performing aggressive pecking behavior, and only 1.39% of the ducks were observed performing self-picking behavior of the total of 288 ducks observed. Frequency and duration of preening behavior increased from Period 1 to Period 2 (frequency: $P = 0.004$; duration: $P < 0.001$), then declined from Period 2 to Period 3 (frequency: $P < 0.001$; duration: $P < 0.001$).

In conclusion, feather pecking between conspecifics was the most frequently performed pecking behavior of commercial Pekin ducks. Age was a major factor affecting the development of pecking behavior, which peaked at 27-29 d. The body locations that injurious pecking behaviors were most frequently directed at were the tail, wings and back, consistent with the welfare condition results that indicated a worsening tail, wing and back feather quality with age. Feather removal and feather eating were infrequently observed, which might indicate that injurious pecking behavior in Pekin ducks is not for the purpose of pulling out and eating the feathers. The frequency and duration of gentle feather pecking and preening behavior followed a similar pattern with age; however, further research is needed to evaluate whether these behaviors are associated. This study provided more details about age-related changes in injurious pecking behavior and welfare of commercial Pekin ducks. However, further work is needed to investigate specific causes of and methods to reduce injurious pecking behavior of Pekin ducks.

CHAPTER 1. LITERATURE REVIEW

The domestic or common duck (Pekin duck) (*Anas platyrhynchos domesticus*) and the Muscovy duck (*Cairina moschata*) are the two most common species of farmed ducks reared throughout the world. Various breeds of duck are produced depending on whether production is for meat or eggs. White Pekin, Muscovy, and Aylesbury ducks are usually raised for meat production, while Khaki Campbell and Indian Runner ducks are often raised for egg production (Coates and Ernst, 2000). The common duck, which originates from the mallard duck (*Anas platyrhynchos*), is present in the Asian, European and the US markets (Rodenburg et al., 2005). Pekin duck is the most popular common duck produced commercially, but the Muscovy duck (originating from Central and South America) is also reared in several European countries (Rodenburg et al., 2005).

About 27.6 million ducks were slaughtered in the United States in 2018 (USDA, 2019), with Indiana, California and Pennsylvania being the top three duck producing states (USDA, 2017). Current amounts of duck consumption are not available from the USDA, but in 2011 Americans consumed about 0.33 lb (0.15 kg) of duck per person (USDA, 2017). Pekin duck production consists of raising ducks in single-age, mixed-sex flocks on a littered floor, raised plastic floor, or a combination thereof. Ducklings are initially brooded in smaller areas of the barn at a higher temperature and then given access to the barn at 3 weeks of age (Karcher and Mench, 2018; Dean and Sandhu, 2019). Once ducks reach a weight of 5 to 7 pounds (at about 6 to 8 weeks of age), they are marketed (Clauer and Skinner, 2007; Coates and Ernst, 2000).

Welfare issues of commercial Pekin ducks have been reviewed in recent papers (Karcher and Mench, 2018; Rodenburg et al., 2005; Colton and Fraley, 2014). Injurious pecking, an umbrella term which groups several pecking behaviors including feather pecking, feather picking, cannibalism and aggressive pecking, is a major welfare issue of commercial Pekin ducks (Karcher and Mench, 2018; Colton and Fraley, 2014), resulting in poor health condition and worse feather quality. While there has been a large amount of research dedicated to injurious pecking behavior of commercial laying hens, very little is known about the development and causes of injurious pecking of Pekin ducks. Colton and Fraley (2014) reported that Pekin ducks picked mostly at themselves, between 17 and 22 days of age, when feathers transition from down to adult plumage. Karcher et al. (2013) reported that the proportion of ducks with worse feather quality scores

increased with age from 7 d to 32 d, and the incidence of dried blood on the tips of primary wing feathers increased with age. However, the extent to which ducks perform self-picking or pecking at their flockmates remains unknown. While previous studies (Karcher et al., 2013; Colton and Fraley, 2014) have examined age-related changes in feather quality changes during welfare assessments, little information is available regarding the frequencies and durations of different pecking and picking behaviors. Furthermore, there does not appear to be any information about the most frequently pecked body locations or the incidences of feather removal and feather eating when Pekin ducks perform feather pecking and feather picking behavior.

1.1 Duck welfare

Before animal welfare issues can be studied, animal welfare needs to be defined. According to Lund et al. (2006), animal welfare is a multidimensional concept that includes scientific, ethical, economic and political aspects. Three main approaches are used to define and assess animal welfare (Fraser et al., 1997): 1) a biological functioning approach (referring to an animal's heath, growth and reproduction); 2) a psychological based approach (animals' feelings and emotions); and 3) a natural living approach (animals' natural behaviors). More recently, a more comprehensive approach to animal welfare with four main aspects was proposed by Dockès and Kling-Eveillard (2006): 1) a biological and technical based approach that emphasizes animals' basic needs and the possibilities to cope with the environment; 2) a regulation approach that considers species compatible conditions because the animal is recognized as being a sensitive being; 3) a philosophical approach that considers animals' roles in human society; and 4) animal human-animal interaction based approach that emphasizes its effects on animal production systems (Carenzi and Verga, 2009). Other organizations have developed definitions of animal welfare that incorporate the three circles approach of Fraser et al. (1997) and the Five Freedoms (FAWC, 1979). For example, the World Organization for Animal Health defines animal welfare as "the physical and mental state of an animal in relation to the conditions in which it lives and dies" (OIE, 2019), and the American Veterinary Medical Association defines animal welfare as "how an animal is coping with the conditions in which it lives" (AVMA, 2019).

1.2 Duck welfare assessment methods and scoring systems

There are welfare assessment protocols available for some poultry species that are used as part of research activities. The Welfare Quality® Assessment Protocol provides instructions to assess the welfare of broiler chickens and laying hens (Welfare Quality®, 2009) and the Animal Welfare Indicators (AWIN) welfare assessment protocol has been developed to assess the welfare of turkeys (Ferrante et al., 2015). However, there is no similar welfare assessment protocol for ducks. Scoring and assessment systems for the welfare of ducks have been reported in a limited number of studies, with some similarities in the level of scores assigned (Table 1.1), but many differences in how the various scores and measures were defined and classified (Table 1.2 – 1.6).

Table 1.1. Summary of welfare measurements and scoring systems used in previous studies.

Study	**Welfare measurements and scoring systems**								
Jones and Dawkins (2010)	Eye condition (score 0-2, D_1)	Nostril condition (score 0, D)	Feather condition (score 0-2, D)	Posture (0-2)	Walking ability (score 0-2)	Feather cleanliness (score 0-3)	Stubby quill	Foot pad dermatitis (score 0-2, IN_1, R_1)	Callous toe
O'Driscoll et al. (2011)	Eye (score 0-3)	Nostril hygiene (score 0-2)			Gait (score 0-5)	Feather hygiene (score 0-3)		Footpad dermatitis (score 0-3)	
Liste et al. (2012b)	Eye (score 0-3)	Nostril hygiene (score 0-2)			Gait (score 0-5)	Feather hygiene (score 0-3)		Footpad dermatitis (score 0-3)	
Karcher et al. (2013)	Eyes (score 0-2)	Nostril cleanliness (score 0-1)	Feather quality (score 0-2)		Gait (score 0-2)	Feather cleanliness (score 0-1)		Heel and toe pads (score 0-2)	
Chen et al. (2015)			Feather condition (score 1-5, tail 1-3)		Gait (score 1-3)				

[1]Scores D, IN and R are defined in Table 1.2, 1.3 and 1.6.

Table 1.2. Definitions of eye condition and nostril cleanliness scores used in welfare measurements from different studies.

Welfare measurements in common	**Score**	**Definition**
Eye condition	0	Best: eyes are clear, clean and bright (Jones and Dawkins, 2010)
		Eye clean, normal color, no inflammation (O'Driscoll et al., 2011)
		Clean, normal color, no inflammation (Liste et al., 2012b)
		Best: eye clear, clean, and bright (Karcher et al., 2013)
	1	Moderate: eyes are wet and weepy or are red rimmed (Jones and Dawkins, 2010)
		Eye red rimmed, weeping slightly, slight crustiness (O'Driscoll et al., 2011)
		Minor lesion: red rimmed, weeping slightly, slight crustiness (Liste et al., 2012b)
		Moderate: dirt or staining around the eye area or any evidence of wet eye ring (Karcher et al., 2013)
	2	Worse: eyes are closed or half closed permanently, or there is conjunctivitis (Jones and Dawkins, 2010)
		Moderate lesion: severely red around rim, much weeping, very crusty (Liste et al., 2012b)
		Severely red around rim, much weeping, very crusty (O'Driscoll et al., 2011)
		Worst: inflamed eye lids, conjunctivitis, eyes sealed shut or blind (Karcher et al., 2013)
	3	Eye not able to open fully, eye closes (O'Driscoll et al., 2011)
		Severe lesion: not able to open fully, or eye is closed (Liste et al., 2012b)
	D	There is a crust or dirt around the outside of the eye (Jones and Dawkins, 2010)
Nostril cleanliness	0	Nostrils are clear and clean (Jones and Dawkins, 2010)
		Clean and clear (O'Driscoll et al., 2011)
		Clean and clear (Liste et al., 2012b)
		Best: nostrils with clean and clear air passage ways (Karcher et al., 2013)
	1	Some blockage visible when viewed from side (O'Driscoll et al., 2011)
		Minor blockage: some blockage visible when viewed from side (Liste et al., 2012b)
		Worst: nostril air passageways blocked with dust or mucus (Karcher et al., 2013)
	2	Nostrils entirely blocked on at least 1 side (O'Driscoll et al., 2011)
		Major blockage: nostrils entirely blocked on at least one side (Liste et al., 2012b)
	D	Nostrils are dirty (Jones and Dawkins, 2010)

Table 1.3. Definitions of feather quality scores used in welfare measurements from different studies.

Welfare measurements in common	**Score**	**Definition**
Feather quality	0	Best: feather cover is even and the feathers are clean (Jones and Dawkins, 2010)
		Best: good coverage of down or feathers (Karcher et al., 2013)
	1	Moderate: feather cover is patchy in wings (Jones and Dawkins, 2010)
		Moderate: some evidence of down/feather picking or damaged area (as evident by short and stubbly down/feathers) less than 1 cm2 (Karcher et al., 2013)
		Perfect plumage (Chen et al., 2015)
	2	Worse: feather cover is patchy or bare on wings and patchy on the back (Jones and Dawkins, 2010)
		Worst: severe feather picking (as evident by blood) or damaged area (as evident by short and stubbly down/feathers) of greater than 2 cm2 (Karcher et al., 2013)
		Feather damaged, no skin area denuded (Chen et al., 2015)
	3	Denuded area up to 3 cm × 3 cm (Chen et al., 2015)
	4	Denuded area greater than 3 cm × 3 cm (Chen et al., 2015)
	5	Completely denuded area (Chen et al., 2015)
	D	Feather cover is even but the feathers are dirty (the degree of soiling was not differentiated) (Jones and Dawkins, 2010)

Table 1.4. Definitions of gait scores used in welfare measurements from different studies.

Welfare measures in common	Score	Definition
Gait	0	Best: the duck waddles and walks freely (Jones and Dawkins, 2010)
		Perfect gait (O′Driscoll et al., 2011)
		Perfect gait (Liste et al., 2012b)
		Best: duck waddles and walks freely (Karcher et al., 2013)
	1	Moderate: the duck walks with a slight limp, or has excessive cross over of the feet or slightly deformed legs (bowed), causing it to walk awkwardly (Jones and Dawkins, 2010)
		Detectable but unidentified abnormality (e.g., uneven gait) (O′Driscoll et al., 2011)
		Detectable but unidentified abnormality (e.g., uneven gait) (Liste et al., 2012b)
		Bird walks with ease, has regular and even strides and is well balanced (Chen et al., 2015)
		Moderate: duck walks with sight limp, or walking is labored due to crossed feet, bowlegs resulting in an awkward gait (Karcher et al., 2013)
	2	Worse: the duck is reluctant to walk and walking is labored, mostly due to severe cases of 1 (Jones and Dawkins, 2010)
		Identifiable abnormality, but little effect on overall function (e.g., lame in 1 leg or crossed legs, but normal speed) (O′Driscoll et al., 2011)
		Identifiable abnormality, little effect on overall function (e.g., crossed legs, 'normal' speed) (Liste et al., 2012b)
		Worst: ducks reluctant to walk, will only walk short distances when encouraged, typically due to obvious leg problems (synovitis, severe crossed feet or extreme bowing of the legs) (Karcher et al., 2013)
		Bird walks with irregular and uneven strides and appears unbalanced (Chen et al., 2015)
	3	Identifiable abnormality and impaired function; obvious gait defect, and bird has difficulty moving (O′Driscoll et al., 2011)
		Identifiable abnormality, impaired function (obvious gait defect, difficulty moving) (Liste et al., 2012b)
		Bird is reluctant to move and is unable to walk many strides before sitting down (Chen et al., 2015)
	4	Severely impaired gait; extreme gait defect, movement is extremely slow, and only after much encouragement, bird sits at first opportunity (O′Driscoll et al., 2011)
		Severely impaired gait (extreme gait defect, very slow movement, bird sits at first opportunity) (Liste et al., 2012b)
	5	Completely lame, mobility severely affected; bird cannot walk, and is mobile only by shuffling on hocks or wings (O′Driscoll et al., 2011)
		Completely lame, mobility severely affected (bird cannot walk, only mobile by shuffling on hocks or wings) (Liste et al., 2012b)

Table 1.5. Definitions of feather cleanliness scores used in welfare measurements from different studies.

Welfare measures in common	Score	Definition
Feather cleanliness	0	Best: feathers are clean (Jones and Dawkins, 2010)
		Minor soiling on less than 10% of feathers, or one small patch of heavy soiling (O′Driscoll et al., 2011)
		<10% of feathers with minor soiling or one small patch of heavy soiling (Liste et al., 2012b)
		Best: clean and unstained down or feathers (Karcher et al., 2013)
	1	Slightly soiled: there is a coating of dirt in the upper layers of feathers (Jones and Dawkins, 2010)
		10 to 40% of feathers affected, soiling minor to moderate; up to 25% affected with heavy soiling (O′Driscoll et al., 2011)
		10%-50% of feathers with minor/moderate soiling or up to 25% affected with heavy soiling (Liste et al., 2012b)
		Worst: adhering manure or staining on down or feathers (Karcher et al., 2013)
	2	Soiled (Jones and Dawkins, 2010)
		40 to 75% of feathers affected, soiling minor to moderate; 25 to 60% affected with heavy soiling (O′Driscoll et al., 2011)
		50%-75% of feathers with minor/moderate soiling or up to 50% affected with heavy soiling (Liste et al., 2012b)
	3	Heavily soiled: the dirt penetrates the under layers of feathers and forms clump (Jones and Dawkins, 2010)
		More than 75% of area affected, soiling minor to moderate; more than 60% of area affected with heavy soiling (O′Driscoll et al., 2011)
		Over 75% of feathers with minor/moderate soiling or over 50% affected with heavy soiling (Liste et al., 2012b)

Table 1.6. Definitions of footpad condition scores used in welfare measurements from different studies.

Welfare measures in common	Score	Definition
Footpad condition	0	Best: the pads are free of lesions and ingrained dirt (Jones and Dawkins, 2010)
		Skin intact with no lesions; slight roughness, but no evident inflammation or discoloration (O′Driscoll et al., 2011)
		Skin intact with no lesions, slight roughness but no inflammation or discoloration (Liste et al., 2012b)
		Best: heel and toe pads free of any lesions or ingrained dirt (Karcher et al., 2013)
	1	Moderate: lesions are visible and cover < 50% of the pad (Jones and Dawkins, 2010)
		Minor lesions: some small areas (<1 cm in diameter) of discoloration or redness (O′Driscoll et al., 2011)
		Minor lesions: some small areas (<1 cm in diameter) of discoloration or redness (Liste et al., 2012b)
		Moderate: pads are callused or cracked but lesions cover less than 50% of the pad area and are free of blood (Karcher et al., 2013)
	2	Severe: lesions are visible, feel deep and cover > 50% of the pad (Jones and Dawkins, 2010)
		Moderate lesions: obvious swelling and much discoloration, roughness; lesions > 1 cm diameter (O′Driscoll et al., 2011)
		Moderate lesions: swelling and much discoloration, roughness, lesions >1 cm diameter (Liste et al., 2012b)
		Worst: lesions or callouses cover 50% or more of pads or any bloody lesions (Karcher et al., 2013)
	3	Severe lesions: severe swelling, scabbing, and ulcers (O′Driscoll et al., 2011)
		Severe lesions: severe swelling, scabbing and ulcers (Liste et al., 2012b)
	IN	Ingrained: ingrained lines filled with dirt transverse the pads (Jones and Dawkins, 2010)
	R	Raised papillae: dirt pervades the pad and the papillae are raised (Jones and Dawkins, 2010)

1.3 Injurious pecking behavior of poultry

Injurious pecking is one of the main welfare concerns for poultry and other captive birds including ducks. Injurious pecking can result in feather damage and wounds to the skin. Feather removal can cause pain to the recipient and this behavior might indicate unfulfilled behavioral needs for the pecker. In severe situations, wounded birds might be pecked to death. Also, feather loss can cause substantial heat loss (Blokhuis, 1998; Lambton et al., 2010; Gentle and Hunter, 1991), affecting efficiency and productivity. Farmers traditionally control the risk of damage from injurious pecking behavior either by beak or bill trimming or by reducing the light intensity in the barn. However, beak/bill trimming can cause both acute and chronic pain and might result in the loss of tactile sense, while reduced lighting can cause abnormal eye development (Lambton et al., 2010). Apart from the welfare issues, injurious pecking is also associated with reduced production, increased mortality and reduced feed conversion ratio, which can lead to economic loss (Gilani et al., 2013). The various types of injurious pecking behavior, including feather pecking, cannibalism, feather picking and aggressive pecking, are described below.

1.3.1 Feather pecking

Feather pecking is an important animal welfare issue of laying hens (Savory, 1995) and turkeys (Duggan et al., 2014); as such, the majority of research into, and information about feather pecking that is available comes from work with laying hens. Reviews by Nicol et al. (2013) and Rodenburg et al. (2013) provide excellent information about feather pecking causes and development.

Feather pecking is not associated with aggression and differs from aggressive pecking in both the body locations that pecking is directed at and the possible reasons for performing the behavior. Feather pecking is usually directed at the body of the bird, whereas aggressive pecking is directed at the head and neck; aggressive pecking is related to the resolution of conflicts whereas feather pecking is not (Bilcik and Keeling, 1999; Kjaer et al., 2001). Feather pecking was first described as damaging pecking or destructive pecking and was classified as one of the “five types of bird-to-bird pecking” (Savory, 1995). Feather pecking is a behavior where one bird pecks at the feathers of a conspecific. Feather pecking is categorized as either gentle feather pecking or severe

feather pecking (Savory, 1995). Gentle feather pecking consists of “light, repeated pecks at the feathers on the tail, wings, back, and neck of the bird”; severe feather pecking consists of “hard, fast, and singular pecks on the tail, back, vent, and neck of the bird” (Daigle, 2017).

The causes of feather pecking are multifactorial in nature, and two main hypotheses that have been proposed to explain the causes of feather pecking include the redirected dustbathing hypothesis and the redirected foraging hypothesis. Based on their results, Vestergaard and Lisborg (1993) hypothesized that there is a possible association between feather pecking and pecking during dustbathing because chickens reared without suitable dustbathing substrates performed more feather pecking. However, Blokhuis (1989) hypothesized that foraging-related ground pecking behavior was the possible explanation of feather pecking, because laying hens performed feather pecking when kept in an environment that lacked a suitable substrate for foraging. Foraging behavior might be motivated by internal factors that drive the bird to perform the behavior even when food consumption is not necessary (Hughes and Duncan, 1988). However, it is hard to say which hypothesis is correct because there is overlap between dustbathing and foraging; the same substrate can be used for both foraging and dustbathing (Dixon, 2009). Moreover, redirected ground pecking is represented in both hypotheses, feather pecking has been observed in the absence of dustbathing, and when dustbathing occurred relatively infrequently (Savory, 1995).

1.3.2 Feather picking

Feather picking has been reported in several poultry species reared under intensive management conditions, especially when birds are reared in environments where they are relatively confined and have few opportunities for exercise (Morishita et al., 1999). Feather picking (also referred as feather plucking), is a form of feather damaging behavior usually seen in psittacine species (but also in ducks). In captive parrots, feather picking is defined as a frequently encountered behavioral disorder, characterized by parrots chewing, biting and/or plucking their own feathers with their beak (van Zeeland et al., 2009), leading to feather and/or skin damage and impaired regrowth of feather (Rosskopf and Woerpel, 1996). In pet birds, feather picking has also been hypothesized to be a psychopathology akin to human compulsive hair pulling (trichotillomania) (Duncan and Hawkins, 2010). Non-medical factors, such as management factors, diet, social isolation and lack of environmental stimuli can also affect the development of feather picking (Mertens, 1997). Lastly, exaggerated preening causing feather removal, instead of

simply grooming, has also been proposed as an explanation of feather picking (Meehan et al., 2003b).

In Samson's (1996) study of ostriches, feather picking is defined as a behavior in which a bird will "aggressively peck feathers from the back and tail area of penmates". Feather picking is often brought about by stress, overcrowding, boredom, and frequently follows a strong seasonal pattern in juvenile and adult birds, being most severe in the winter months because of prolonged confinement (Samson, 1996). In a study of Pekin ducks, Colton and Fraley (2014) referred the "occasionally auto-mutilation behavior" as feather picking. Feather picking appears to coincide with the transition from duck downy feathers to adult plumage, between 17 and 22 d of age. Early studies used the term "feather picking" and "feather pecking" interchangeably; for example, Dickerson et al. (1961) (cited by Cuthbertson, 1978), and Bearse et al. (1949) (cited by Kjaer and Bessei, 2013). However, more recent studies consider feather pecking and feather picking to be distinct. In contrast to feather pecking, which is directed by one bird to another (particularly in galliforms), feather picking has been described as a self-damaging behavior that occurs in psittacine species such as parrots and ducks (see Colton and Fraley, 2014).

1.3.3 Cannibalism

Cannibalism, which includes tissue pecking and vent pecking, can occur either independently or following feather pecking (Blokhuis, 1998). When pecks are then directed at bald patches of skin exposed due to severe feather pecking, bleeding can result (Savory, 1995), and in severe cases, bleeding and tissue damage can lead to the death of pecked birds (Rodenburg, 2013). Vent pecking refers to pecking that is directed at the vent area, which may begin as a form of investigatory pecking but then progress to removal of abdominal organs ("pick out") and even death because of blood loss (Savory, 1995). There is no clear relationship between cannibalism and any kind of feather pecking because there has been no scientific support that cannibalism occurs to a higher degree or continues from feather pecking (Hughes and Duncan, 1972). According to Allen and Perry (1975), feather pecking and cannibalism can be affected by similar environmental conditions, but are not directly associated because cannibalism often occurred before high levels of feather pecking were observed, and vent pecking was reported to have no association with feather pecking.

1.3.4 Aggressive pecking

Although aggressive pecking is a form of injurious pecking, aggressive pecking is different from other injurious pecking behaviors because aggression is not believed to be a cause of other injurious pecking behaviors. Establishing a social rank is a normal part within a social group. Aggressive pecking is usually used to establish and maintain the hierarchy among birds (Rodenburg et al., 2013; Birkl et al., 2017). Aggressive pecks are forceful pecks which are usually directed at the head or other parts of the body if the pecker has no access to the recipient's head, and aggressive pecking always leaves the impression of the pecker's intention to hurt. Aggressive pecking usually occurs between dominant birds and subordinates to resolve competitions and establish and maintain dominance, and aggressive pecking occurring within a "normal, adaptive" range does not result in severe injuries (Savory, 1995; Bilcik and Keeling, 1999; Kjaer et al., 2001; Dalton et al., 2013). However, in certain situations, aggressive pecking can become more intense or more severe than typical, escalating and causing significant damage. Aggressive pecking is particularly problematic in groups of male turkeys, being severe enough to lead to death in some cases (Dalton et al., 2013).

1.4 Injurious pecking in different species of poultry and captive birds

1.4.1 Ducks

There are only limited numbers of studies about injurious pecking behavior of ducks. Feather pecking, cannibalism and feather picking were reported in Pekin ducks and Muscovy ducks (Riber and Mench, 2008; Rodenburg et al., 2005; Colton and Fraley, 2014). Muscovy ducks housed on slatted floors without litter perform feather pecking behavior (Rodenburg et al., 2005). Cannibalism occurs in Muscovy ducks as well, and has been observed as early as 13 days of age (Riber and Mench, 2008), possibly in conjunction with the growth of the first feathers (Snyder, 1962; von Faber, 1964). Unlike chickens, the redirected foraging hypothesis and redirected preening hypothesis do not explain the underlying motivation of feather pecking and cannibalism in Muscovy ducks (Riber and Mench, 2008). In addition, Klemm et al. (1995) reported less feather pecking in mixed groups of Muscovy and Pekin ducks. For Pekin ducks, Colton and Fraley (2014) reported that self-picking happened most frequently, with the occasional feather pecking between

conspecifics. The changes in a duck's appearance, such as the appearance of blood, can attract other ducks and lead to pecking.

1.4.2 Chickens

Three types of injurious pecking behavior occur in chickens, including feather pecking, cannibalism and aggressive pecking. Injurious pecking is a major welfare concern for laying hens, affecting large numbers of hens in various types of housing systems. Severe feather pecking was reported to result in feather damage and mortality in laying hens (Savory, 1995). Most occurrences were reported during the laying period (Newberry et al., 2007, Bright, 2009) but severe feather pecking can also occur during the rearing period (Blokhuis and van der Haar, 1992, Johnsen et al., 1998, Riedstra and Groothuis, 2002, de Haas et al., 2014b). Previous studies reported 65% to 69% of flocks during the laying period in free range systems and 86% of organic systems are affected by severe feather pecking (Gilani et al., 2013; Lambton et al., 2013; Bestman and Wagenaar, 2003). During the rearing period, the affected percentage is 27% in free range systems and 54% in organic systems (Gilani et al., 2013; Bestman et al., 2009). Feather damage was observed during rearing and during the laying period in approximately 90% of cases (Gilani et al., 2013; Bestman et al., 2009). In another study, de Haas et al. (2014a) found feather damage mainly on the back during rearing and mainly on the neck during the laying period. They stated that feather damage on the back most likely indicated severe feather pecking, while aggressive pecking most likely caused feather damage on the neck, particularly when inadequate feed was provided. Another study reported that 17% of total mortalities in two commercial laying hen flocks was caused by cannibalism from 21 to 54 weeks of age Tablante et al. (2000), indicating that cannibalism can be a serious welfare issue in commercial laying hen flocks.

1.4.3 Turkeys

Injurious pecking is a major welfare concern for turkeys on commercial farms, resulting in mortality and necessitating culling. The same types of injurious pecking reported for laying hens, aggressive pecking, feather pecking, and cannibalism, occur among turkeys (Dalton et al., 2013). Injurious pecking was reported to take up 6% of the total daily activity budget of female turkeys from 1 to 12 weeks of age (Hughes and Grigor, 1996). Investigatory preening of debris was

assumed to be the underlying motivation for gentle feather pecking, while redirected foraging (because of the absence of suitable substrate) was associated with severe feather pecking (Martrenchar, 1999; Sherwin et al.,1999; Dixon et al., 2008). In the presence of environmental or social disturbances, increased activity levels and aggressive pecking can occur in turkey flocks for the purpose of re-establishing the dominance hierarchy (Dalton et al., 2018; Cunningham et al., 1992; Buchwalder and Huber-Eicher, 2003, 2004). In addition to environmental influences on injurious pecking behavior of turkeys, there is a sex difference in the prevalence of injurious pecking. Injurious pecking was observed to peak in males at 3 weeks of age, compared to 9 weeks of age for females (Dalton et al., 2013).

1.4.4 Pheasants

Injurious pecking has also been reported in pheasants. Feather pecking and cannibalism are the major types of injurious pecking reported. Feather pecking is considered by some to be related to feeding instinct (Hoffmeyer, 1969). In one study, a type of pecking similar to feather pecking was observed a few days after hatching (Hoffmeyer, 1969). This type of pecking was directed at the feet, bill, cloaca and wings, and pheasants were often observed pecking at body locations where new feathers were just appearing or in growth (Hoffmeyer, 1969). Feather pecking on the tail and back were reported to occur independently, while feather pecking on the wings and back were considered to be correlated (Madsen, 1966; Hughes and Duncan, 1972). Pecking at the cloacal region was not considered to be associated with any kind of feather pecking (Hughes and Duncan, 1972). Cannibalism was reported to be prevalent in pheasant chicks raised in confinement and changes in lighting condition influenced the incidence of cannibalism (Cain et al., 1984).

1.4.5 Parrots

Pet birds, such as parrots, are housed and managed differently compared to commercial or backyard poultry; the majority of pet birds are housed singly for a variety of reasons that can include the practicality of housing the birds alone, and cost and space considerations (Meehan et al., 2003a). Feather picking is a major behavioral concern of parrots that is influenced by several factors. Van Zeeland et al. (2009) stated that the development of feather picking behavior is associated with sexual maturity, prolonged reproductive behavior, changes in hormone levels

during the mating season, as well as dry air during cold times of the year. Several theories have been proposed to explain the motivation of feather picking behavior of parrots. Meehan et al. (2003b) suggested the redirected foraging hypothesis of laying hens can apply to feather picking as well, but van Zeeland et al. (2009) proposed that feather picking may be similar to some disorders of humans (trichotillomania, TTM, and obsessive compulsive disorder, OCD), because feather picking may be regulated and influenced by neurotransmitters; in particular, dopamine (DA) and serotonin (5-hydroytryptamine, 5-HT), or may be influenced by brain dysfunction. Serotonin is believed to be associated with abnormal repetitive behaviors including OCD and TTM (Stein, 2000). Similarly, the dopaminergic system has been linked with obsessive-compulsive symptoms, as well as playing a role in self-injurious behavior (Stein et al., 1999). Ramsay and Grindlinger (1994) also posit that feather picking of psittacine birds is similar to OCD in humans. They evaluated clomipramine (a tricyclic antidepressant drug which is thought to act as a serotonin reuptake inhibitor), which has been effective for treating human OCD, as a treatment to reduce psittacine birds' feather picking. The results suggested that clomipramine may be effective in treating feather picking only in some birds because self-mutilating birds were used in their study, but self-mutilation in humans is recognized as a different disorder from OCD and is usually treated with different categories of medication.

1.4.6 Japanese Quails

Similar to chickens and turkeys, feather pecking, cannibalism and aggressive pecking are associated with injury in Japanese quails (Kirkwood et al., 2010; Wechsler and Schmid, 1998). However, unlike laying hens, the re-directed foraging hypothesis was not supported for the mechanism of feather pecking behaviors in Japanese quails (Miller and Mench, 2006). Aggressive pecking was reported to occur both in intensive systems and semi-natural outdoor aviaries (Schmid and Wechsler, 1997). Aggressive pecking was reported to be affected by litter materials, where aggressive pecking events were the highest on dried mud and the lowest on sawdust (Mohammed et al., 2017). Recoquillay et al. (2013) reported high correlations between sexual motivation and aggressive pecking in both phenotypic and genetic dimensions; male sexual motivation and aggressive pecking are both regulated by testosterone.

1.5 Development of injurious pecking behavior

The development of injurious pecking behavior has been studied in several poultry and captive bird species. In laying hens, Lambton et al. (2010) reported increased rates of feather pecking from 5 to 14 weeks of age and decreased rates by 20 weeks of age. Positive correlation of feather pecking rates was found between 14 and 20 weeks of age, which indicated feather pecking during rearing period can affect its rates during laying period. Gilani et al. (2013) also reported that gentle feather pecking significantly decreased by 35 weeks of age, while severe feather pecking significantly increased with age. In turkeys, gentle and severe feather pecking were most frequent at 3 to 6 weeks of age then declined by 9 weeks of age (Busayi et al., 2006). In ducks, injurious pecking may be related to the transition from down to adult feathers, which occurred at 17-22 d (Colton and Fraley, 2014).

1.6 Factors affecting injurious pecking development and occurrence

The factors affecting injurious pecking in different poultry and captive bird species including chickens, turkeys and parrots are summarized in Table 1.7.

Table 1.7. Summary of factors affecting injurious pecking development and occurrence in different poultry and bird species.

Poultry and captive bird species	**Factors affecting injurious pecking**	**References**
Chickens	**Environmental and management factors:** Beak trimming, stocking density, flock ranging, access to perches, delayed access to litter at point of lay (POL), temperature, variation in humidity, light intensity, air quality, noise level, variation in sound/light levels, pelleted feed, type of feeders, diet change during rear, and change in farm from rear to lay. **Internal factors:** Age, genetic predisposition, hormonal fluctuations, activity level and temperament traits, deficiencies in certain nutrients, and inadequate provision of fiber.	Widowski et al., 2017; Mellor et al., 2018
Turkeys	**Environmental factors:** Stocking density, lighting, ventilation, humidity, temperature, flies or ectoparasites, the presence of dead or limping birds, early environment, the level of familiarity between group members, diet form, frequency, or ingredients, and amount of feed provided. **Internal factors:** The appearance of ultraviolet (UV) feather markings on the wings and tail in the first week of age.	Leighton et al., 1985; Classen et al., 1994; Hughes and Duncan, 1972; Ensminger, 1992; Jendral and Robinson, 2004; Allain et al., 2013; Hale and Schein, 1962; Hughes and Grigor, 1996; Hamilton and Kennie, 1997; Dalton, 2013; Sherwin and Devereux, 1999; Moinard et al., 2001
Parrots	**Environmental factors:** The absence of parents at an early age and deprivation of a social or sexual partner, exposure to other animals or humans, and inappropriate responses of the owner. **Internal factors:** Abnormal brain function, neurotransmitter deficiencies and medical causes.	Davis, 1991; Gylstorff and Grimm, 1998; Wedel, 1999; Low, 2001; Seibert, 2006; Ramsay and Grindlinger, 1994; Davis, 1991; Rosenthal, 1993; Juppien, 1996; Gylstorff and Grimm; 1998; Welle, 1999; Low, 2001; Seibert, 2006. Van Zeeland, et al., 2009

1.7 Aims of this project

Injurious pecking behavior is one of the major behavioral issues affecting the welfare of poultry and other captive birds, including commercial Pekin ducks. Reduced welfare and increased flock mortality, reduced production efficiency, reduced feed conversion ratio, and economic loss have been reported for chickens, turkeys and ducks (Gilani et al., 2013; Dalton et al., 2013; Pingel, 1999). Although the development and characteristics of injurious pecking have been studied in other poultry and captive bird species including chickens, turkeys, parrots and Japanese quails, few studies have examined injurious pecking behavior of Pekin ducks. In particular, no previous study has provided details about the characteristics and development of injurious pecking in Pekin ducks on commercial farms. Therefore, this study examined the prevalence and age-related changes in frequencies and durations of injurious pecking and preening behavior of commercial Pekin ducks, the body locations most frequently affected, and whether feather removal and feather eating occurred concurrently with injurious pecking as well as age-related changes in duck welfare that may be associated with injurious pecking behavior.

CHAPTER 2. INJURIOUS PECKING BEHAVIOR OF PEKIN DUCKS ON COMMERCIAL FARMS: CHARACTERISTICS, DEVELOPMENT AND DUCK WELFARE

2.1 Abstract

Injurious pecking behavior, including feather pecking and feather picking, greatly affects commercial Pekin duck welfare. This study investigated characteristics of injurious pecking behavior of ducks, including 1) the prevalence, frequency and duration of injurious pecking, 2) age-related changes injurious pecking and preening behavior; 2) body locations affected, 3) occurrence of feather removal and feather eating; and 4) changes in duck welfare that may be associated with injurious pecking. Duck welfare (feather quality, feather cleanliness, nostril cleanliness, eye condition, footpad condition and gait) was assessed for 100 ducks/flock in 5 commercial flocks (5 farms) between 17-18 d (Period 1), 29-30 d (Period 2), and 36-37 d (Period 3). Behavior of two flocks was video-recorded at 20-22d (Period 1), 27-29 d (Period 2), and 34-36 d (Period 3) and analyzed using scan (n = 53192 ducks/flock) and focal (n = 144 ducks/flock) animal sampling. Data were analyzed using the MIXED and GLIMMIX procedures (SAS 9.4). Severe feather pecking (SFP), aggressive pecking (AGGP) and forceful self-picking (SELFP) were combined into one category for analysis.

Duck welfare scores (except neck feather quality) worsened with age. The proportion of ducks performing GFP ($P < 0.001$), and the frequency ($P < 0.001$) and duration ($P < 0.001$) of GFP and other pecking behaviors (frequency: $P = 0.038$; duration: $P = 0.036$) increased with age. GFP was the most frequently observed behavior and increased from Period 1 to 2 ($P < 0.001$), then declined from Period 2 to 3 ($P = 0.0002$). Preening frequency and duration similarly changed with age. Body locations affected by GFP included the tail, wings and back. From scan sampling, 90.94% of ducks performed GFP, 1.85% SFP, 6.84% AGGP; no SELFP was observed. From focal sampling, 83.33% of ducks performed GFP, 13.89% SFP, 16.67% AGGP, and 1.39% performed SELFP. Feather removal and feather eating occurred infrequently. Feather pecking between conspecifics was the most frequently performed pecking behavior, and age was a major factor affecting both duck welfare and the occurrence of injurious pecking behavior.

2.2 Introduction

Injurious pecking is one of the main welfare concerns for poultry and other captive birds including commercial Pekin ducks. Injurious pecking behavior can result in feather and skin damage, pain, substantial heat loss because of feather loss, and even death of the recipient bird (Blokhuis, 1998; Lambton et al., 2010). Injurious pecking behavior is associated with reduced production, increased mortality and reduced feed conversion ratio, which can lead to economic losses (Gilani et al., 2013).

Injurious pecking behavior includes feather pecking, feather picking, cannibalism and aggressive pecking. Feather pecking refers to when a bird uses its beak or bill to peck at the feathers of a conspecific and can be categorized as either gentle feather pecking (light and repeated pecks) and severe feather pecking (hard, fast, and singular pecks) (Savory, 1995; Daigle, 2017). Although feather pecking and feather picking are sometimes used interchangeably, feather picking is self-damaging behavior that occurs in psittacine species such as parrots and in ducks (van Zeeland et al., 2009; Colton and Fraley, 2014), whereas feather pecking refers to pecking between conspecifics. Cannibalism can occur either independently or following feather pecking (Hughes and Duncan, 1972; Blokhuis and Wiepkema, 1998). The majority of research into cannibalism has focused on laying hens. Based on the laying hen research, the two forms of cannibalism are tissue pecking (persistently forceful pecks directed at exposed skin) and vent pecking (pecks directed at the top of the cloaca or below the cloaca) (Savory, 1995). Unlike feather picking, feather pecking and cannibalism, which are not associated with aggression, aggressive pecking is associated with establishing and maintaining the dominance hierarchy (Savory, 1995).

The development and characteristics of injurious pecking behavior have been studied in chickens, turkeys, pheasants, parrots and Japanese quails. Various factors affect the prevalence and development of injurious pecking, including age, beak trimming, stocking density, temperature, humidity, ventilation, light intensity, air quality, noise level, diet change, nutrient deficiencies, hormonal fluctuations, neurotransmitter deficiencies, and medical causes (Widowski et al., 2017; Mellor et al., 2018; Dalton, 2013; van Zeeland, et al., 2009).

Other studies have examined feather pecking and cannibalism in Muscovy ducks and have reported the occurrence of cannibalism at 13 d (Riber and Mench, 2008), and growth of the first feathers was assumed to be associated with cannibalism (Snyder, 1962; von Faber, 1964). Muscovy ducks housing on slatted floor without litter was reported to perform feather pecking

behavior (Rodenburg et al., 2005). Decreased level of feather pecking was reported in mixed groups of Muscovy and Pekin ducks (Klemm et al., 1995). Seasonal change was reported to affect feather pecking and feather picking of ducks. Increased amount of feather pecking and feather picking was reported periods with temperature and weather changes during the spring and fall (Colton and Fraley, 2014; Huber-Eicher and Sebö, 2001). Different flooring substrates were reported as a possible factor affecting feather pecking and feather picking. More feather picking was reported in European Union systems using slatted flooring than those using straw (Rodenburg et al., 2005). Ducks reared on 100% litter or a mix of 50:50 slats:litter were reported to perform less feather picking than those housed with 100% slatted floor (Rodenburg et al., 2005; Leipoldt, 1992).

Although the Pekin duck is the most common species in commercial meat duck production, limited research has examined injurious pecking of Pekin ducks. One study examined the effects of environmental enrichment on feather picking and feather pecking, and reported that "the worst incidences of feather picking occurred in less than 3%" of the ducks examined and Pekin ducks were reported to pick mostly at themselves and occasionally at each other (Colton and Fraley, 2014). Feather picking is reported to occur between 17 and 22 days of age, when duck feather cover transitions from down to adult plumage (Colton and Fraley, 2014). Another study examined the influence of raised plastic floors compared with pine shaving litter on Pekin ducks' welfare condition. The proportion of ducks with worse feather quality scores increased with age from 7 d to 32 d, and the incidence of dried blood on the tips of primary wing feathers increased with age (Karcher et al, 2013). Previous studies examined how feather quality changes due to age, but several questions about injurious pecking behavior of ducks remain unanswered. In particular, the frequencies and durations of feather pecking and feather picking behavior (how prevalent the behavior is) and how these behaviors change with age have not been directly examined. The body locations targeted have not been examined either; information about body locations could provide insight into whether injurious pecking is related to feather growth on specific body locations. Lastly, previous research with chickens linked feather eating with the performance of feather pecking behavior (Bessei and Kjaer, 2015; Meyer et al., 2012; Meyer et al., 2013; Zhao et al., 2013), but the incidence of feather removal and feather eating when Pekin ducks perform feather pecking and feather picking behavior have not been examined. Therefore, the objectives of this study were to investigate 1) the prevalence of injurious pecking behavior, 2) age-related changes

in frequencies and durations with which ducks perform different types of injurious pecking and preening behavior; 2) the body locations most frequently involved, 3) whether feather removal and feather eating happened frequently with injurious pecking behavior; and 4) changes in duck welfare that may be associated with injurious pecking.

2.3 Materials and Methods

2.3.1 Animals and housing

All procedures used in this study were approved by the Purdue Animal Care and Use Committee (PACUC). Data were collected from June to July (2018) in 5 commercial duck flocks, each located on a different farm. Welfare data were collected from all 5 flocks and behavior data were collected from 2 (flock 1 and flock 2) of the 5 flocks. As per industry practice, the ducks were raised in starter barns from 1 d of age until approximately 18 d of age, then moved to grower barns until about 42 d when they were sent to slaughter. Starter barn dimensions were 33.8 m × 12.5 m. Grower barn dimensions were 87.5 m × 12.5 m; each held between 5750 to 7500 ducks with flock density ranging between 0.18 to 0.19 m^2 per duck (Table 2.1). The barns were curtain-sided and had litter areas and raised plastic-slatted floor areas equipped with feeders and nipple drinker lines (Fig. 2.1). Sawdust was used as bedding in the litter area of each barn. Ducks were raised under industry standards: environmental temperatures were kept at a minimum of 24 °C and brooders were on during the first 7 days. After the removal of brooders, environmental temperatures ranged between 13-30 °C. Relative humidity in the barn ranged between 50-70%, natural ventilation was used (fans were on during warmer periods to keep the temperature below 30 °C) and lighting condition followed a natural daylight schedule. Nipple drinker lines were provided at a ratio of at least 1 nipple per 12 ducks and 8 feeders (diameter of 0.8 m) were provided in each grower barn. All ducks were bill-trimmed. Ducks were provided feed and water *ad libitum*.

Table 2.1. Housing conditions for each duck flock.

Flock	Number of ducks at placement	Size of the barn (m^2)	Flock density (space (m^2) per duck)
1	5895	1093.19	0.19
2	5737	1093.19	0.19
3	5992	1093.19	0.18
4	7088	1293.21	0.18
5	5991	1093.19	0.18

2.3.2 Duck welfare assessment

The welfare of 100 ducks in each of the five flocks was assessed at 17-18 d (Period 1), 29-30 d (Period 2), and 36-37 d (Period 3). Twenty ducks were sampled in each of five predetermined locations in the barn (4 corners and middle of the barn). Groups of ducks (n = 20) were separated at each location using hinged catching frames, and individual ducks within each group were scored by one to two team(s) of two observers/team, using a modified scoring rubric of Karcher et al. (2013) and the American Humane Certified™ Meat Ducks (Common/Domestic Ducks) Animal Welfare Standards Audit Tool (American Humane Association, 2019) (Table 2.2). The individual characteristics were scored on a scale of 0 to 1 (nostril and feather cleanliness) or 0 to 2 (eyes, feather quality, footpad quality, and gait) where 0 was the best or ideal condition and a 1 or 2 indicated a worsening condition for that specific characteristic. Welfare-assessment teams attended an on-farm training in scoring ducks and scored the same ducks before each assessment until consensus was reached, after which they continued to score ducks independently.

Table 2.2. Duck welfare criteria scores and definitions adapted from Karcher et al. (2013) and the American Humane Association (2019).

Condition	Score	Definition
Eyes	0	Best: eyes clear, clean, and bright
	1	Moderate: dirt or staining around the eye area or any evidence of wet eye ring
	2	Worst: Inflamed eye lids, conjunctivitis, eyes sealed shut or blind
Nostril cleanliness	0	Best: Nostrils with clean and clear air passageways
	1	Worst: Nostril air passageway (either side) blocked with dust or mucus
Feather cleanliness	0	Best: Clean and unstained down or feathers
	1	Worst: Adhering manure or staining on down or feathers
Feather quality	0	Best: Good coverage of down or feathers
	1	Moderate: Feather damage without blood (e.g. short and stubby down/feathers) or bald patch less than 1 cm^2
	2	Worst: Severe feather damage (e.g. blood) or bald patch of greater than 2 cm^2
Footpads	0	Best: free of any lesions or ingrained dirt
	1	Moderate: Pads are callused or cracked but lesions cover less than 50% of the pad area and are free of blood
	2	Worst: Lesions or callouses cover 50% or more of pads or any bloody lesions
Gait	0	Best: Duck waddles and walks freely
	1	Moderate: Duck walks with slight limp, or walking is labored due to crossed feet, bowlegs resulting in an awkward gait
	2	Worst: Ducks reluctant to walk, will only walk short distances when encouraged, typically due to obvious leg problems (synovitis, severely crossed feet or extreme bowing of the legs)

2.3.3 Behavioral observations

Video recording. Duck behavior in the grower barns was recorded for flocks 1 and 2 over two continuous days before (Periods 2, 27-29 d, Period 3, 34-36 d) and after (Period 1, 20-22 d) welfare assessments were conducted. Because commercial duck barns are very large, it was not feasible to record the entire barn area. Therefore, sections of each barn (2 sections over the litter area and 1 section over the slatted (feeder and drinker) area; Fig. 2.1) were randomly selected for recording. To be able to randomly select recording areas, each barn was divided into 135 (27 columns × 5 rows) sections, in which numbers 1-54 represented the slatted area, and numbers 55-135 represented the litter area. The width of each row (2.5 m) and column (3.2 m) were measured and small pieces of tape on the barn wall were used to mark rows and columns to help locate sections for setting up cameras. Three video cameras (GoPro HERO 5 Black Model number: ASST1, GoPro Inc., San Mateo, CA) were used to record between 900h and 1500h. The video

settings used were 1080p video resolution (RES), 30 FPS and SuperView field of view (FOV). Cameras were positioned at a height of 3 m from the floor to record approximately 136 m^2 of floor area; each camera FOV thus captured 17 of the numbered sections (12.43% of the barn/camera; 37.29% total barn area captured by all 3 cameras). For analysis of video recordings, each camera's FOV was then divided into 8 equal squares from which 4 were randomly selected using computer-generated numbers (Haahr, 2010). Thus, 4 squares, representing half of each camera's FOV (68 m^2 of barn floor) were ultimately analyzed using both focal animal and scan sampling to examine duck behavior.

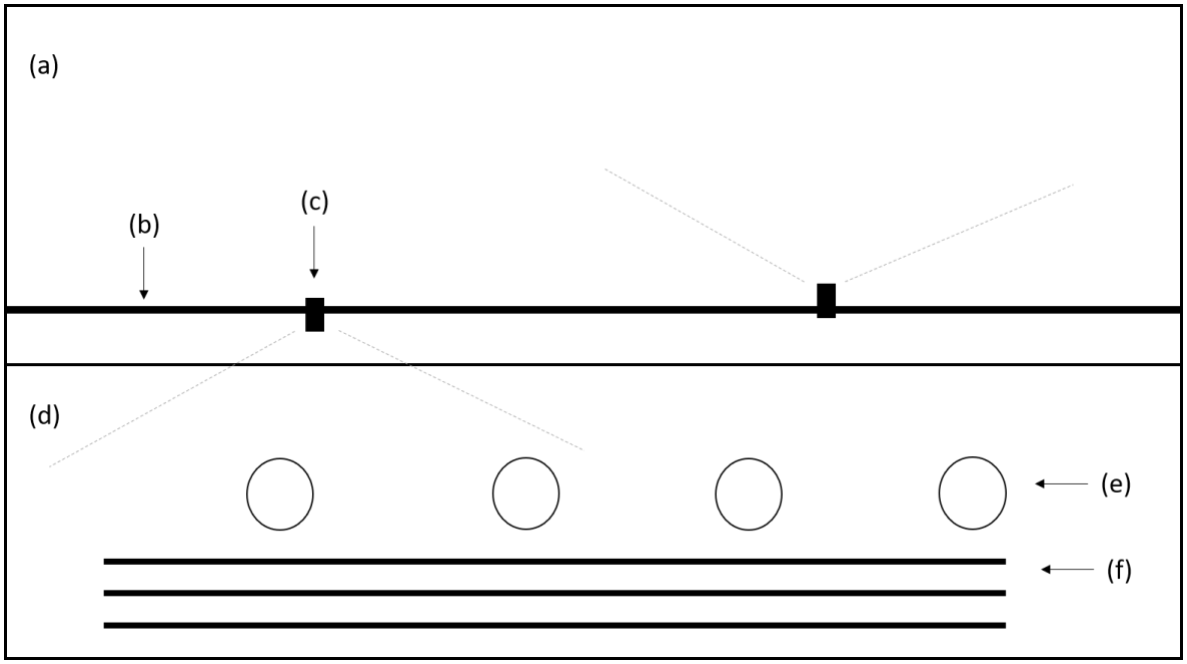

Figure 2.1. Camera placement in the commercial production environment. The litter area (a) and raised plastic-slatted floor area (d) equipped with feeders (e) and nipple drinker lines (f) had a bar near the ceiling (b) on which cameras were mounted (c).

Scan sampling. Videos were sampled every 30 min from 0900h to 1500h. The number of ducks performing each type of injurious pecking behavior listed in the ethogram (Table 2.3) was counted at the start of every 30 min observation period so that the proportion of ducks performing each behavior could be calculated from the total number of ducks present in the observation area and used for statistical analysis.

Table 2.3. Description of duck behavior (modified from Savory, 1995; Daigle, 2017; van Zeeland, 2009; Nuechterlein and Storer, 1985; Barrett et al., 2019; Jones and Dawkins, 2010 and Liste et al., 2012a).

Behavior	**Description**
Gentle feather pecking (GFP)	Gentle, repeated nibbling at the feathers. Usually ignored by the recipient, eliciting no response, and the recipient usually does not move away from the pecker (Savory, 1995; Daigle, 2017).
Severe feather pecking (SFP)	Forceful, fast, and singular pecks at the feathers. The feather is grasped and firmly pulled, and the recipient may move away from the performer. Sometimes the feather is removed and may be eaten (Savory, 1995; Daigle, 2017).
Forceful self-picking (SELFP)	The bird either chews, bites and/or plucks its own feathers forcefully with its bill (van Zeeland et al., 2009).
Aggressive pecking (AGGP)	Pecks usually aimed at the head, but sometimes at other parts of the body if the head is inaccessible. Pecks may be combined with forward motions and/or pushing. The bird might attempt to grasp the neck or body of its opponent or chase its opponent. Pecks are delivered with considerable force, giving the impression that they are intended to hurt. (Savory, 1995; Daigle, 2017; Nuechterlein and Storer, 1985; Barrett et al., 2019).
Preening	The duck nibbles at or strokes its feathers with its bill, maintaining its plumage (Liste et al., 2012a; Jones and Dawkins, 2010).

Focal animal sampling. Videos were analyzed by three trained observers (inter-rater reliability using Pearson's correlation coefficient was 0.95). For each day of recorded video, data were collected from 30-minute video segments (0945h to 1015h and 1345h to 1415h). The ducks in each observation area were numbered at the beginning of the 30 min period (at 0945h and 1345h), and from these ducks, one was randomly selected for focal sampling (n = 8 ducks per camera (4 ducks in the morning and 4 ducks in the afternoon) and 24 ducks per flock) and observed for each 30-min period to determine the duration and frequency of injurious pecking behavior (Table 2.3). The pecked body locations, whether feather removal and feather eating occurred concurrently with injurious pecking and ducks' role (recipient or pecker) for each pecking interaction were also recorded. During the observation period, if the duck left the observation area before the 30 min observation was complete, another duck was randomly selected and observed for as long as the chosen duck remained visible in the observation area until the end of the 30-min observation period (if the duck did not remain in the observation area, another was selected and so on). There were 159 out of 288 focal ducks for which alternative ducks were selected during the 30 min observation period.

2.3.4 Statistical analysis

All statistical analyses were performed using SAS software Version 9.4 (SAS Institute Inc., Cary, NC). Differences among periods in welfare measures were analyzed using PROC GLIMMIX with the random intercept statement using flock as the subject. Welfare scores were either multinomial (welfare measures with score 0-2) or binomial (welfare measures with score 0-1). Results were reported as odds ratio estimates.

Scan sampling data were subjected to repeated measures analysis using PROC MIXED. Only GFP data were analyzed because other injurious pecking behaviors happened too infrequently for analysis; descriptive statistics for these behaviors have been provided in the results section. Factors in the model included period, location in the barn (litter area or slatted area), time of day and their interactions. The response variable was the proportion of ducks performing GFP. Flock was the random effect. Timepoints nested within each period was the repeated measure. Results were reported as least square (LS) means of the proportion of ducks performing GFP ± standard error (SE). Post-hoc pair-wise comparisons were examined using Tukey's test.

For focal sampling, data were recorded as the number of times a behavior occurred (frequency) and the duration of the behavior. The MIXED procedure was used to analyze duration data and PROC GLIMMIX was used to analyze frequency data. SFP, AGGP and SELFP were combined into one category for analysis because they occurred infrequently. Preening duration was normalized using square root transformation. Durations of GFP and combined SFP, AGGP and SELFP data were normalized using a log(x+1) transformation. All frequency data were normalized using a log(x+1) transformation. Factors in the model included period, location in the barn, time of day and their interactions. Flock was included as a random effect and day of video recording nested within each week was included as a repeated measure. Results were reported as transformed least square (LS) means ± standard error (SE). Back-transformed least square (LS) means were reported. Post-hoc pair-wise comparisons of least-squared means were examined using Tukey′s test. Statistical significance was considered at $P \leq 0.05$.

2.4 Results

2.4.1 Duck welfare

Age significantly affected the majority of duck welfare measures: feather quality (neck: $F_{2,1492}$ = 13.85, P < 0.001; back: $F_{2,1472}$ = 61.14, P < 0.001; left wing: $F_{2,1492}$ = 152.29,P < 0.001; right wing: $F_{2,1492}$ = 159.73, P < 0.001; tail: $F_{2,1472}$ = 150.17, P < 0.001), eye condition ($F_{2,1472}$ = 59.42, P < 0.001), gait ($F_{2,1472}$ = 17.91, P < 0.001), footpad condition (left footpad: $F_{2,1472}$ = 23.65, P < 0.001; right footpad: $F_{2,1472}$ = 22.10, P < 0.001), and cleanliness (nostril: $F_{2,1473}$ = 6.88, P = 0.001; breast: $F_{2,1473}$ = 40.49, P < 0.001; back: $F_{2,1473}$ = 21.08, P < 0.001; rump: $F_{2,1473}$ = 6.26, P = 0.002; under the tail: $F_{2,1473}$ = 180.20, P < 0.001), except for neck cleanliness ($F_{2,1493}$ = 2.25, P = 0.105). Pairwise comparisons revealed that the likelihood of having better welfare (better feather quality, feather cleanliness, eye condition, footpad condition and gait) decreased with age (Table 2.4 and Table 2.5). For example, at Period 1 (17-18 d), the likelihood of ducks having a better back feather quality was approximately 2-7 times greater than the likelihood of having a better back feather quality at Period 2 (29-30 d) (P < 0.001), and 6-20 times more likely than at Period 3 (36-37 d) (P < 0.001). Results were similar for all other body locations (except for the neck); the likelihood of having better welfare scores were highest at Period 1 compared to Period 2 and Period 3, and higher at Period 2 than at Period 3. The opposite was observed for neck feather quality, where neck feather quality was best at Period 2 and worst at Period 1, with neck feather quality being intermediate at Period 3, but still different from the other ages.

Nostril cleanliness was significantly worse at Period 2 compared to nostril cleanliness at Period 1 and Period 3, with no differences in nostril cleanliness between Period 1 and Period 3. Neck cleanliness did not change over time. Breast cleanliness was better at Period 1 than at Period 3 (P < 0.001), but did not differ between Period 1 and Period 2. Ducks at Period 2 were approximately 3-7 times more likely to have better breast cleanliness than at Period 3 (P < 0.001). Similarly, back cleanliness was worse at Period 3 compared to Period 1 and Period 2, but did not differ between Period 1 and Period 2. Rump cleanliness was better at Period 2 compared to Period 1 and Period 3, but did not differ between Period 1 and Period 3. Cleanliness under the tail was best at Period 1 and worsened with increased age.

Eye condition was best at Period 1 and worsened with age. Gait was better at Period 1 compared to Period 2 and Period 3, but did not differ between Period 2 and Period 3. The condition

of both the left and right footpads were best at Period 2 and worst at Period 1, with footpad condition being intermediate at Period 3, but still different from the other periods.

Table 2.4. Probability and odds ratio estimates for the influence of age (Period 1 = 17-18 d, Period 2 = 29-30 d, Period 3 = 36-37 d) on duck welfare measures.

Welfare measure	**Odds ratio estimate (lower - upper), P-value**		
	Period 1 vs. 2	**Period 1 vs. 3**	**Period 2 vs. 3**
Feather quality[1]			
Neck	0.039 - 0.3128, **P < 0.001**[2]	0.305 - 0.9802, **P = 0.04**	1.679 - 14.764, **P < 0.001**
Back	2.045 – 6.958, **P < 0.001**	6.4724 – 20.623, **P < 0.001**	2.071 - 4.529, **P < 0.001**
Left wing	1.249 - 3.196, **P = 0.001**	9.642 - 22.915, **P < 0.001**	5.174 - 10.7, **P < 0.001**
Right wing	1.245 - 3.154, **P = 0.001**	10.035 - 23.648, **P < 0.001**	5.42 - 11.155, **P < 0.001**
Tail	1.7443 – 7.5707, **P < 0.001**	23.625 - 93.347, **P < 0.001**	8.243 - 20.272, **P < 0.001**
Cleanliness			
Nostril	1.034 - 2.178, **P = 0.028**	0.573 - 1.281, P = 1.000	0.389 - 0.838, **P = 0.001**
Neck	0.207 - 1.268, P = 0.232	0.525 - 2.307, P = 1.000	0.879 - 5.241, P = 0.122
Breast	0.642 - 2.121, P = 1.000	2.876 - 7.932, **P < 0.001**	2.521 - 6.639, **P < 0.001**
Back	0.792 - 2.566, P = 0.444	2.092 - 5.965, **P < 0.001**	1.545 - 3.973, **P < 0.001**
Rump	0.0945 - 0.660, **P = 0.002**	0.481 - 1.790, P = 0.784	1.397 - 9.887, **P = 0.004**
Under the tail	4.976 - 10.415, **P < 0.001**	16.695 - 37.866, **P < 0.001**	2.451 - 4.976, **P < 0.001**
Other measures			
Eye condition	3.1941 - 18.352, **P < 0.001**	11.298 - 61.087, **P < 0.001**	2.275 - 5.175, **P < 0.001**
Gait	1.902 - 5.6827, **P < 0.001**	2.155 - 6.365, **P < 0.001**	0.749 – 1.693, P = 1.000
Left footpad	0.317 - 0.575, **P < 0.001**	0.532 - 0.951, **P = 0.015**	1.237 - 2.242, **P < 0.001**
Right footpad	0.325 - 0.592, **P < 0.001**	0.457 - 0.824, **P < 0.001**	1.039 - 1.885, **P = 0.021**

[1]Feather quality of the head was assessed; however, only 8 birds received a score of 1 and no birds had a score of 2.

[2]All significant results (P < 0.05) have been bolded

Table 2.5. Percentage of ducks with each welfare score (Period 1 = 17-18 d, Period 2 = 29-30 d, Period 3 = 36-37 d).

Welfare measure	Percentage of ducks								
	Period 1			Period 2			Period 3		
	0	1	2	0	1	2	0	1	2
Feather quality									
Head	99.4%	0.6%	0%	99.6%	0.4%	0%	99.4%	0.6%	0%
Neck	90.2%	5.4%	4.4%	98.8%	0.8%	0.4%	94.2%	5.8%	0%
Back	95.6%	2.4%	2.0%	85.8%	6.2%	8.0%	67.4%	14.2%	18.4%
Left wing	90.6%	7.4%	2.0%	83.2%	13.0%	3.8%	41.4%	42.2%	16.4%
Right wing	90.4%	7.0%	2.6%	82.8%	13.2%	4.0%	39.8%	39.8%	20.4%
Tail	97.0%	3.0%	0%	90.2%	9.6%	0.2%	48.6%	45.2%	6.2%
Cleanliness									
Nostril	81.4%	18.6%		74.6%	25.4%		83.6%	16.4%	
Neck	95.8%	4.2%		97.8%	2.2%		95.4%	4.6%	
Breast	93.4%	6.6%		92.4%	7.6%		75.8%	24.2%	
Back	93.85	6.2%		91.45	8.6%		81.2%	18.8%	
Rump	94.0%	6.0%		98.4%	1.6%		94.4%	5.6%	
Under the tail	84.4%	15.6%		43.6%	56.4%		18.4%	81.6%	
Other measures									
Eye condition	98.2%	1.6%	0.2%	88.0%	11.2%	0.8%	69.0%	29.2%	1.8%
Gait	94.2%	5.4%	0.4%	83.4%	15.6%	1.0%	82.0%	16.0%	2.0%
Left footpad	32.2%	51.25	16.6%	53.2%	37.8%	9.0%	42.6%	40.8%	16.6%
Right footpad	32.2%	48.6%	19.2%	47.2%	45.8%	7.0%	40.2%	48.2%	11.6%

2.4.2 Duck behavior

Scan sampling

Gentle feather pecking

The proportion of ducks performing GFP was significantly influenced by age ($F_{2,301}$ = 10.35, P < 0.001; Fig. 2.2) and time of day ($F_{1,301}$ = 4.18, P = 0.042; Fig. 2.3), while location in the barn did not have a significant effect ($F_{1,301}$ = 0.06, P = 0.804; Fig. 2.4). The average proportion of ducks performing GFP peaked at Period 2 (Period 1 vs. Period 2, P = 0.0004), then declined to Period 3 (Period 2 vs. Period 3, P < 0.001), and did not differ between Period 1 and Period 3 (Fig. 2.2). The average proportion of ducks performing GFP was significantly higher in the morning than in the afternoon (P = 0.042; Fig. 2.3).

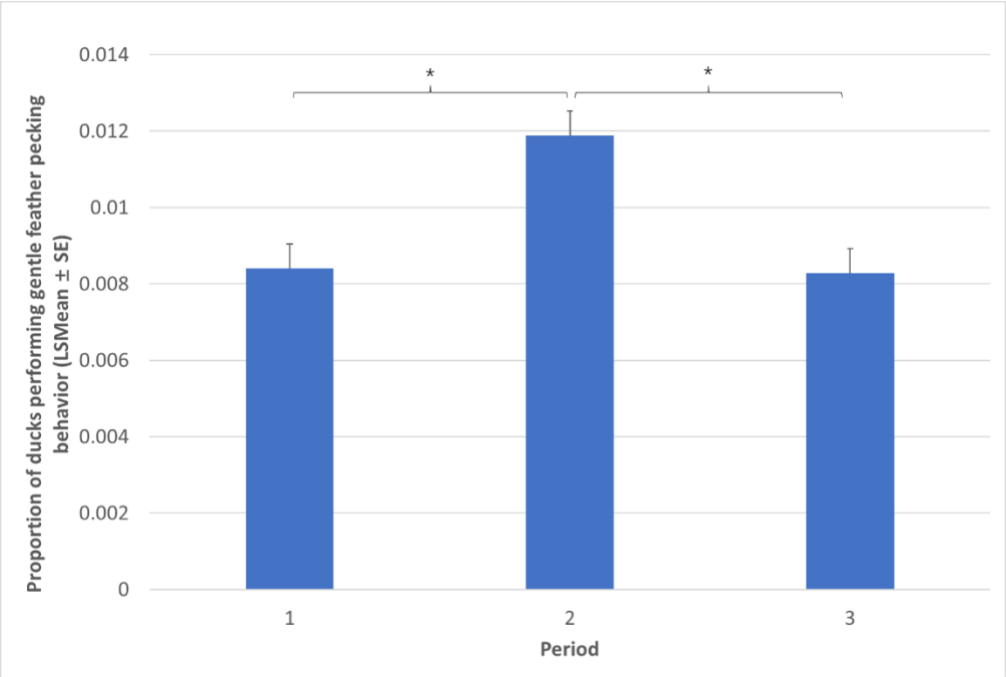

Figure 2.2. Proportion of ducks performing GFP (LSMean ± SE) at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d). * P < 0.001.

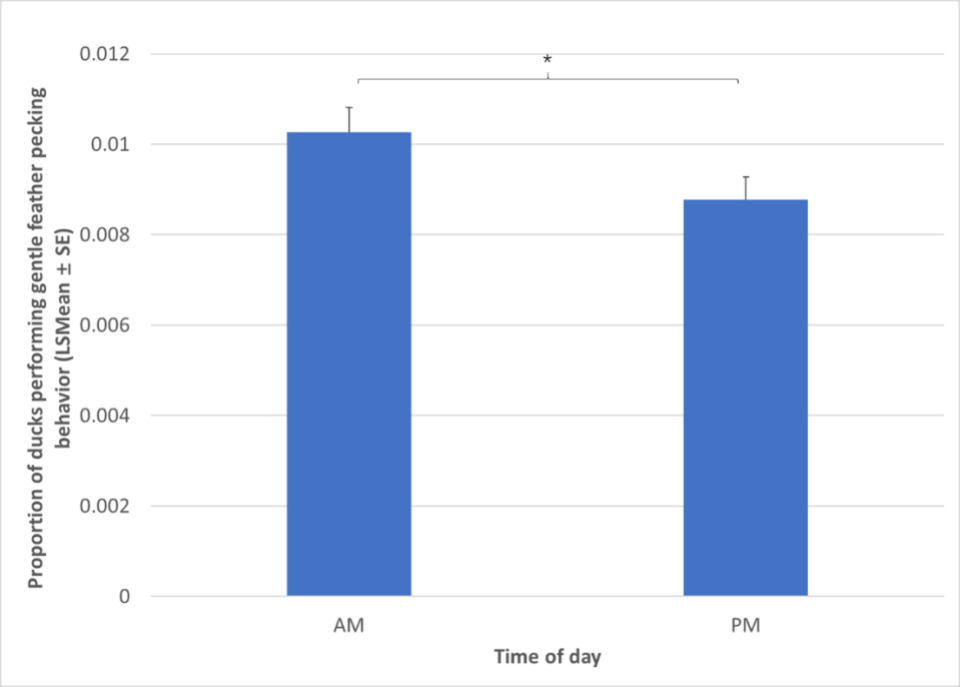

Figure 2.3. Proportion of ducks performing GFP (LSMean ± SE) during the morning (AM) and afternoon (PM). * $P < 0.05$.

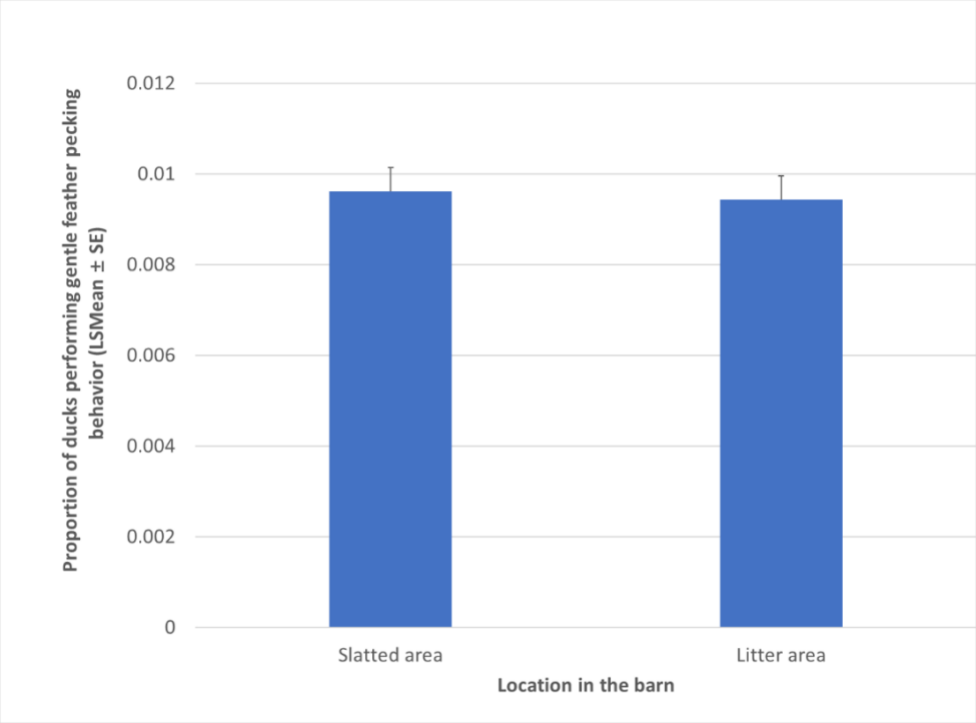

Figure 2.4. Proportion of ducks performing GFP (LSMean ± SE) in one of two locations in the barn.

The proportion of ducks performing GFP in the morning or afternoon depended on the location in the barn (Fig. 2.5). The proportion of ducks performing GFP was significantly higher in the slatted area than in the litter area in the morning ($P = 0.034$) but the opposite was observed in the afternoon ($P = 0.05$). The proportion of ducks performing GFP from morning to afternoon depended on the location in the barn. The proportion of ducks performing GFP was significantly higher in the morning compared to the afternoon in the slatted area ($P < 0.001$), but did not differ between morning and afternoon in the litter area ($P = 0.618$).

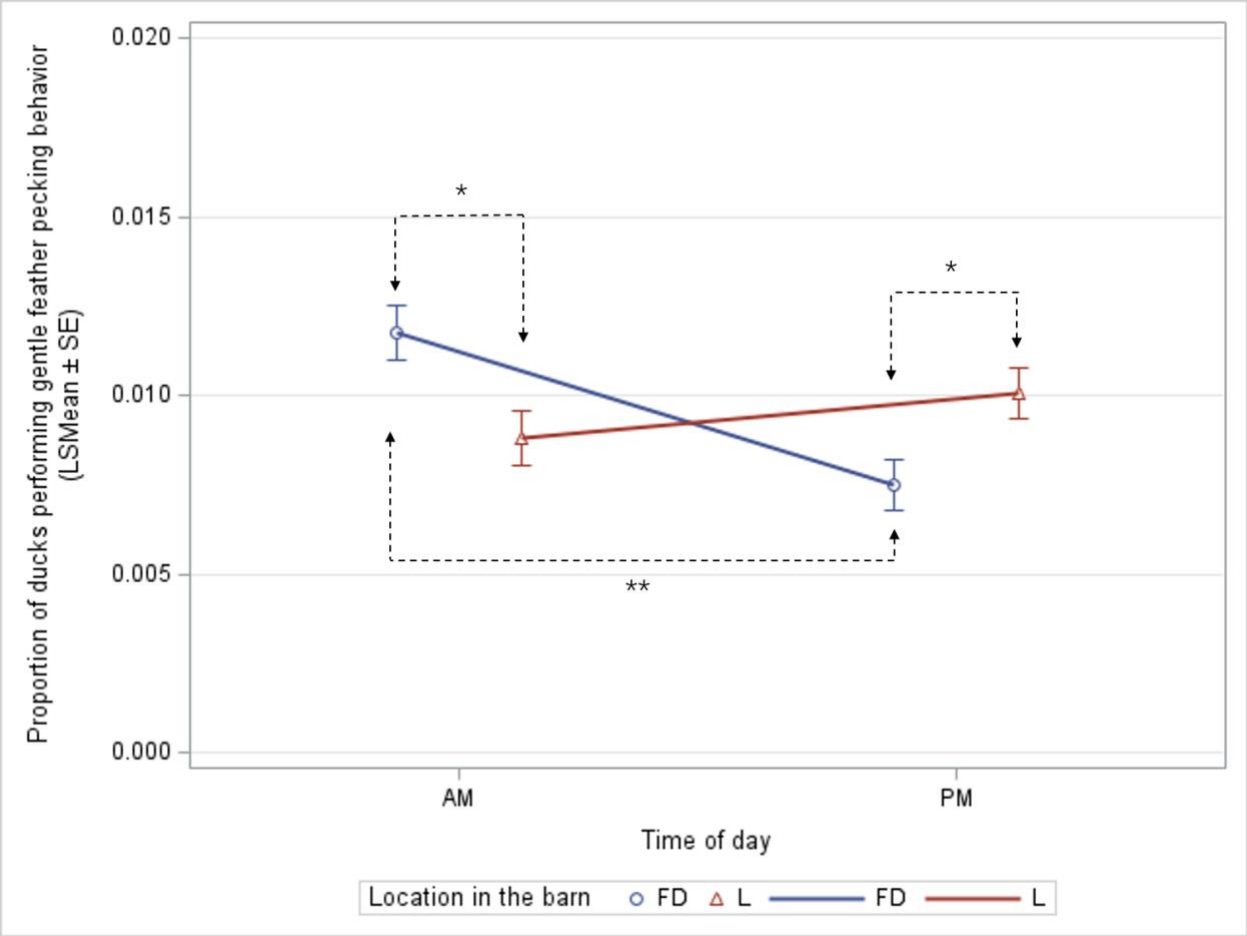

Figure 2.5. Proportion of ducks performing GFP (LSMean ± SE) in one of two locations in the barn (FD = slatted area, L = litter area) during the morning (AM) and afternoon (PM). * $P < 0.05$, ** $P < 0.001$.

The proportion of ducks performing GFP at different ages depended on the location in the barn (Fig. 2.6). The proportion of ducks performing GFP was significantly higher in the litter area

compared to the slatted area for Period 1 ($P < 0.001$). The opposite was observed for Period 3 ($P = 0.034$) and did not differ between locations for Period 2 ($P = 0.396$). Within each location in the barn, there were age-related differences in the proportion of ducks performing GFP. In the slatted area, GFP peaked at Period 2 (Period 1 vs. Period 2, $P < 0.001$) and did not differ between Period 2 and Period 3 ($P = 0.2$), and was higher at Period 3 compared to Period 1 ($P = 0.004$). In the litter area, the proportion of ducks performing GFP was significantly lower in Period 3 compared with Period 1 ($P = 0.002$) and Period 2 ($P = 0.01$), but did not differ between Period 1 and Period 2 ($P = 0.998$).

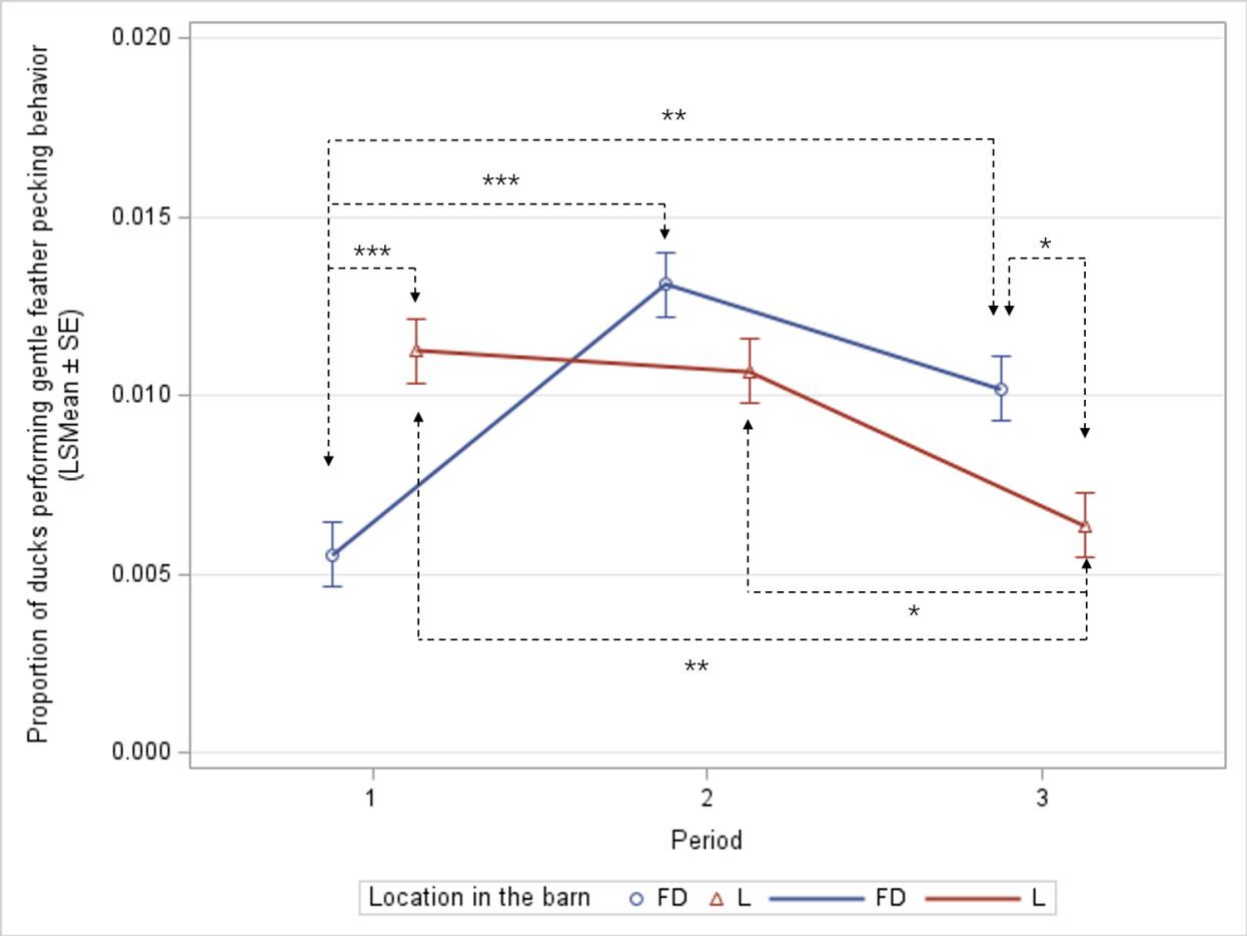

Figure 2.6. Proportion of ducks performing GFP (LSMean ± SE) at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d) and location in the barn (FD = slatted area, L = litter area). * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

The proportion of ducks performing GFP at different ages depended on the time of day (Fig. 2.7). For Period 1 and Period 3, no differences were found between the morning and afternoon, but the proportion of ducks performing GFP was significantly higher in the morning compared to the afternoon for Period 2 ($P = 0.0054$). Age-related differences in the proportions of ducks performing GFP in the morning and afternoon were found. The proportion of ducks performing GFP in the morning peaked at Period 2 (Period 1 vs. Period 2, $P < 0.0001$) and declined to Period 3 (Period 2 vs. Period 3, $P = 0.0005$), but did not differ between Period 1 and Period 3 ($P = 0.9985$). No significant differences were found when comparing the proportion of ducks performing GFP in the afternoon among Periods.

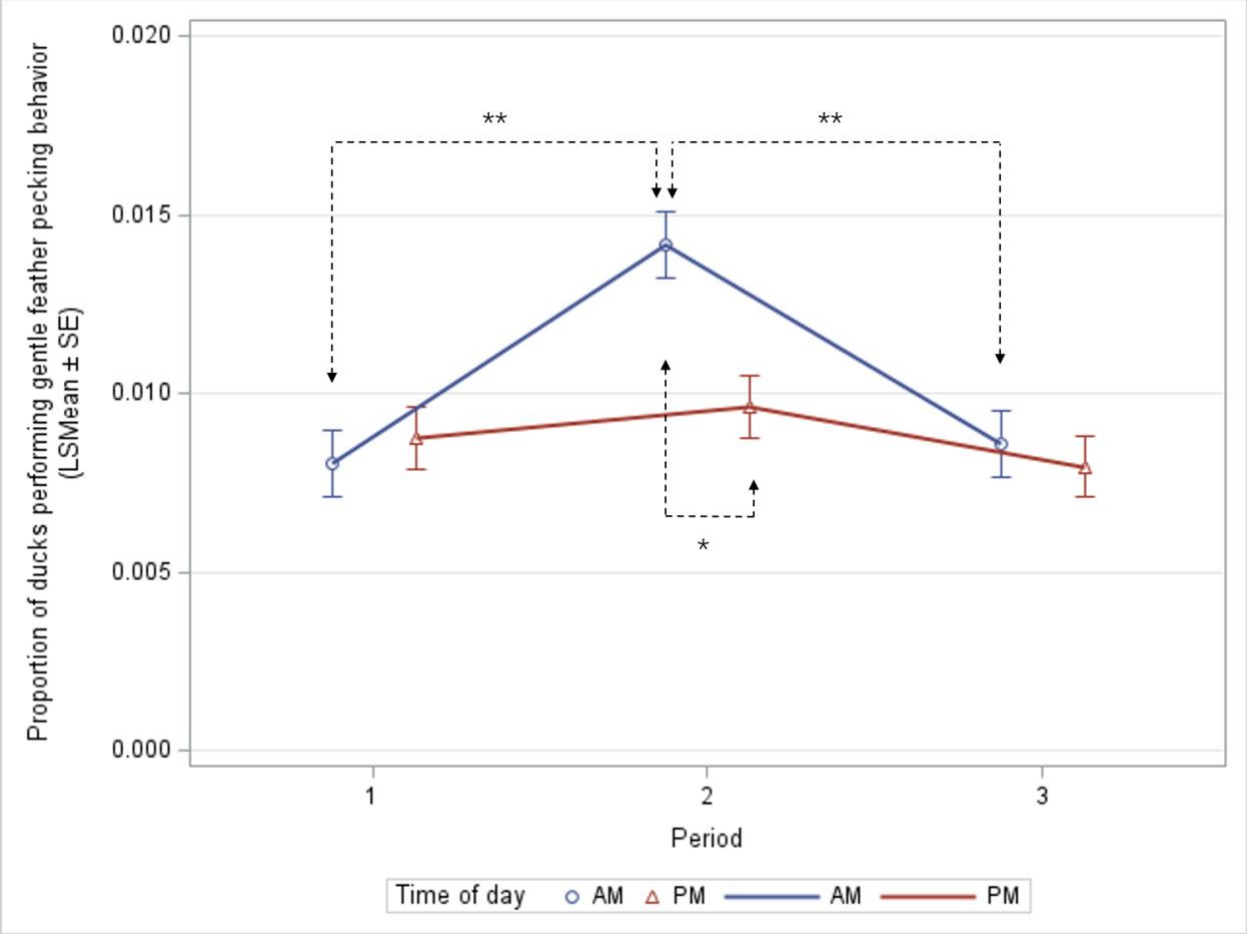

Figure 2.7. Proportion of ducks performing GFP (LSMean ± SE) at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d) during the morning (AM) and afternoon (PM). * $P < 0.01$, ** $P < 0.001$.

Severe feather pecking, aggressive pecking and forceful self-picking

In addition to GFP, SFP, AGGP and SELFP were also recorded. However, these injurious pecking behaviors occurred too infrequently to be analyzed statistically. A total number of 20 birds were observed performing SFP across all 6 days of video observation. SFP was observed at 6 timepoints (2 timepoints in the morning and 4 timepoints in the afternoon) across all 6 days of video observation. A total number of 74 birds were observed performing AGGP during 10 timepoints (5 timepoints in the morning and 5 timepoints in the afternoon) across all 6 days of video observation. No instances of SELFP were observed.

Focal sampling

Frequency of preening

The frequency of preening behavior was significantly influenced by time of day ($F_{1,277}$ = 6.56, P = 0.011) and age ($F_{2,277}$ = 17.55, P < 0.001). Location in the barn did not affect preening frequency ($F_{1,277}$ = 0.09, P = 0.765). No significant interaction effect was found (Age × time of day: $F_{2,277}$ = 1.05, P = 0.352; Location in the barn × time of day: $F_{1,277}$ = 3.81, P = 0.052; Age × location in the barn: $F_{2,277}$ = 0.31, P = 0.736). Average preening frequency was significantly lower in the morning compared to the afternoon (P = 0.011; Fig. 2.8), and peaked at Period 2 (Period 1 vs. Period 2, P = 0.004) then declined to Period 3 (Period 2 vs. Period 3, P < 0.001). Frequency of preening was also higher in Period 3 compare to Period 1 (P = 0.024; Fig. 2.9).

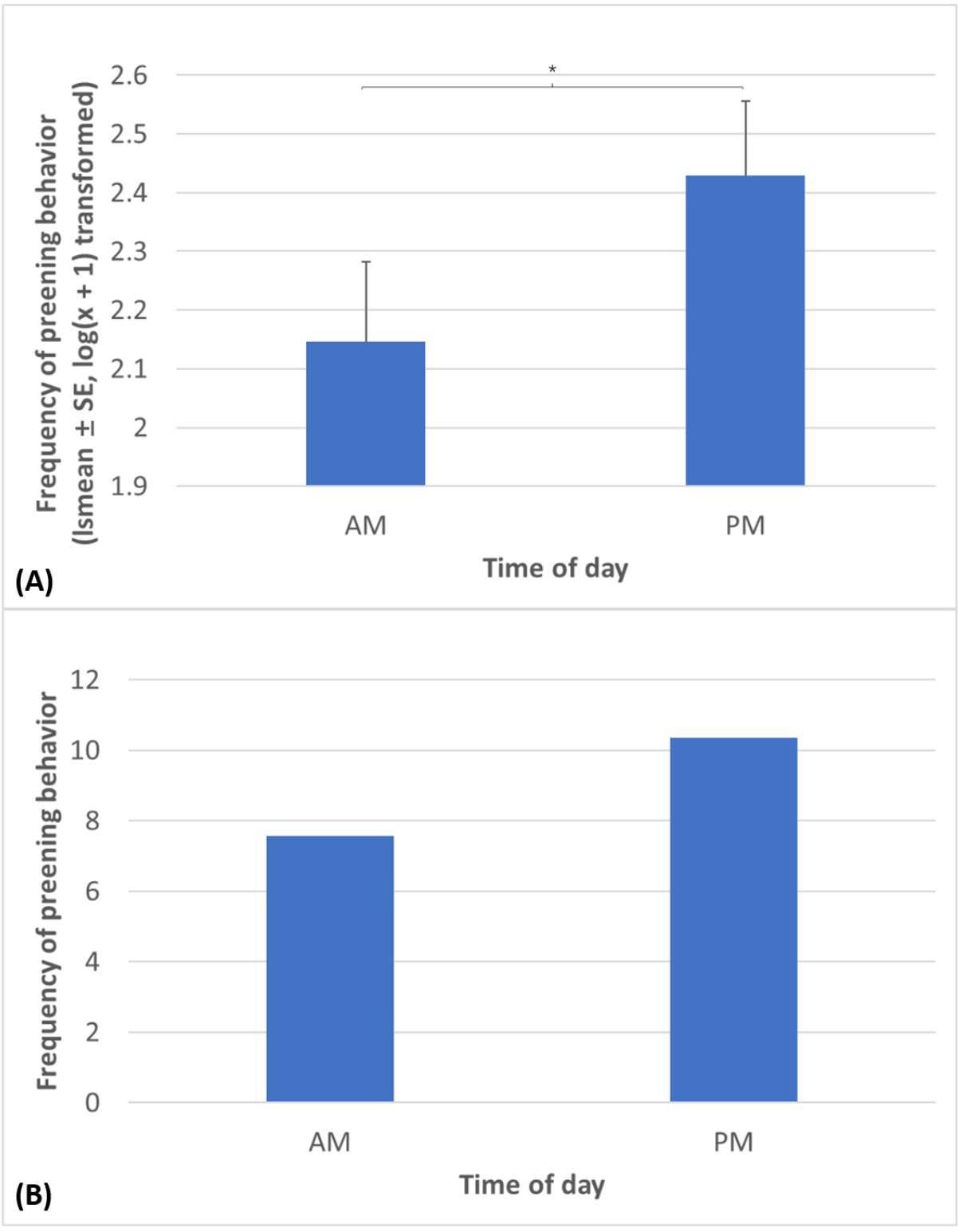

Figure 2.8. Frequency of preening behavior occurring during the morning (AM) and afternoon (PM). Log(x+1) transformed LSMeans ± SE are reported in (A) and back transformed LSMeans are reported in (B). *P < 0.05.

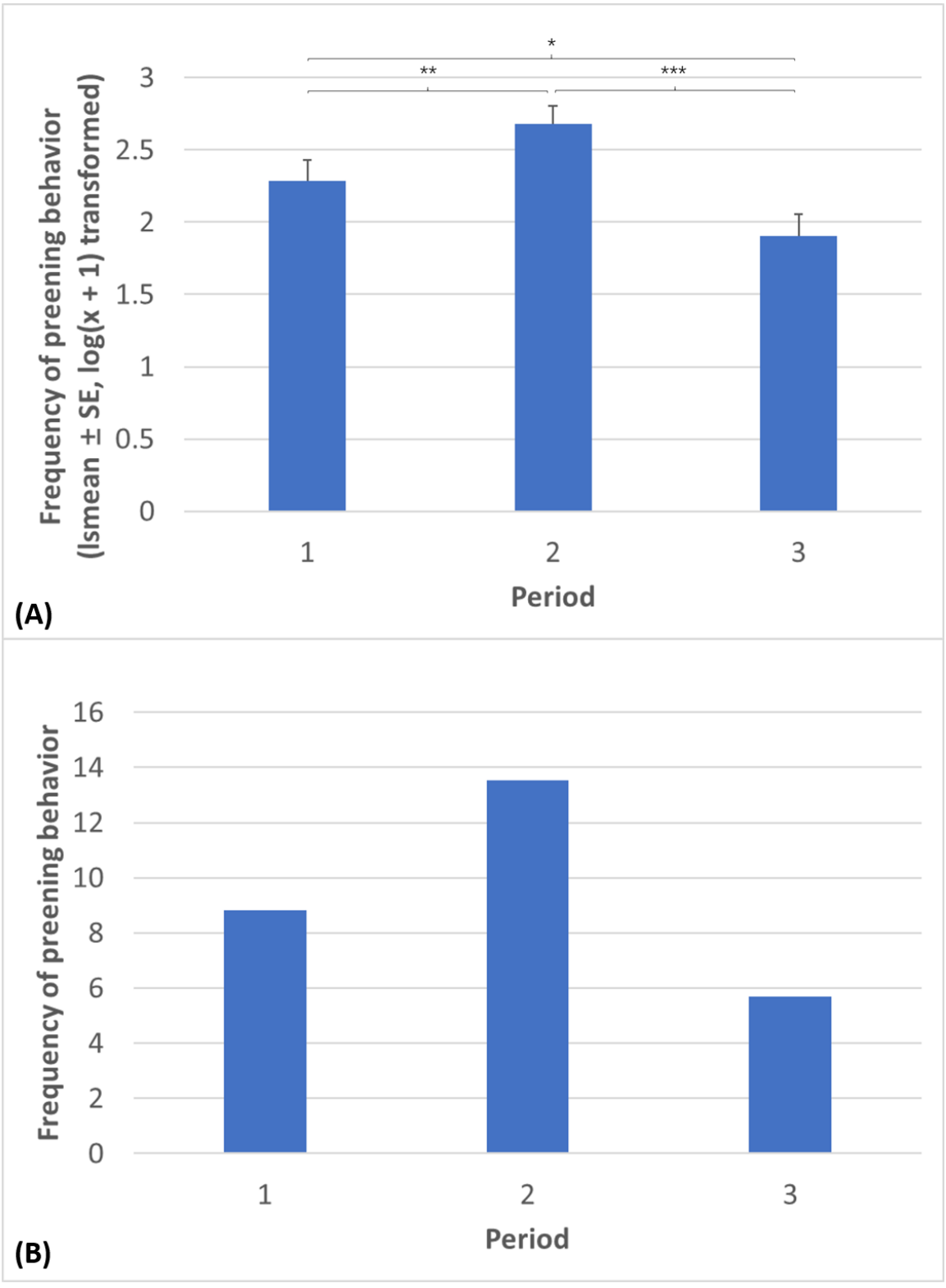

Figure 2.9. Frequency of preening behavior occurring at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d). Log(x+1) transformed LSMeans ± SE are reported in (A) and back transformed LSMeans are reported in (B). * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Frequency of gentle feather pecking

The frequency of GFP was significantly influenced by age ($F_{2,277}$ = 41.25, P < 0.001). Time of day ($F_{1,277}$ = 0.21, P = 0.649) and location in the barn ($F_{1,277}$ = 0.42, P = 0.515) did not affect the frequency of GFP. No significant interaction effects were found (Age × time of day: $F_{2,277}$ = 0.64, P = 0.527; Location in the barn × time of day: $F_{1,277}$ = 0.15, P = 0.699; Age × location in the barn: $F_{2,277}$ = 0.80, P = 0.45). The average frequency of GFP peaked in Period 2 (Period 1 vs. Period 2, P < 0.001) and declined to Period 3 (Period 2 vs. Period 3, P < 0.001; Fig. 2.10).

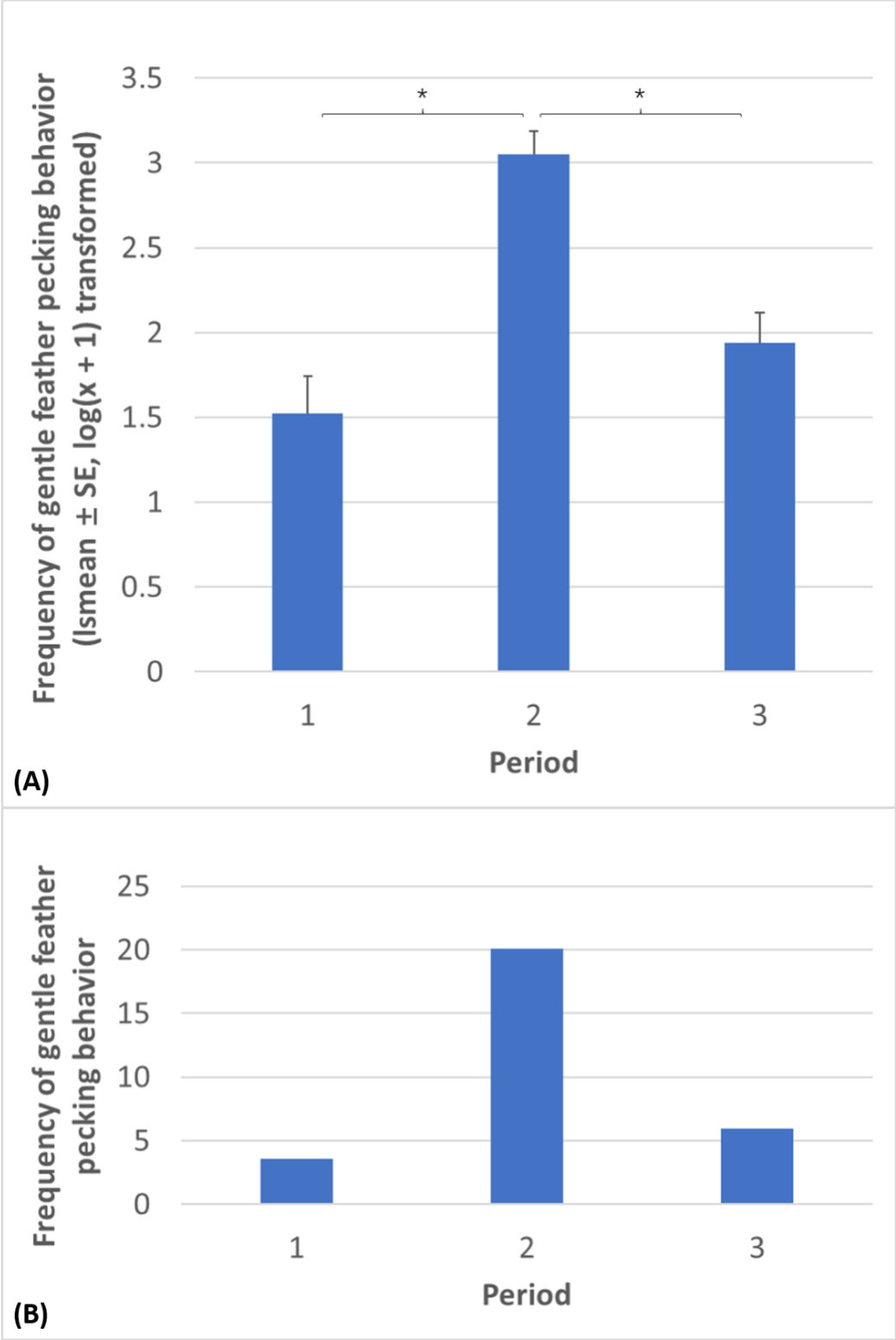

Figure 2.10. Frequency of GFP at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d). Log(x+1) transformed LSMeans ± SE are reported in (A) and back transformed LSMeans are reported in (B). * P < 0.001.

Frequency of severe feather pecking, aggressive pecking and forceful self-picking

SFP, AGGP and SELFP were observed relatively infrequently. Therefore, the frequencies of these behaviors were combined for statistical analysis. The combined frequency of SFP, AGGP and SELFP was significantly influenced by age ($F_{2,277}$ = 3.32, P = 0.038) and the interaction effect between age and location in the barn ($F_{2,277}$ = 3.32, P = 0.038). Time of day ($F_{1,277}$ = 1.90, P = 0.169) and location in the barn ($F_{1,277}$ = 0.279, P = 0.603) did not affect the combined frequency of SFP, AGGP and SELFP. Other interaction effects did not influence the combined frequency of SFP, AGGP and SELFP either (Age × time of day: $F_{2,277}$ = 1.91, P = 0.151; Location in the barn × time of day: $F_{1,277}$ = 0.03, P = 0.038). The combined frequency of SFP, AGGP and SELFP was significantly higher at Period 2 compared to Period 1 (P = 0.03) and did not differ compared to Period 3 (Fig. 2.11). The frequency of these behaviors at different ages depended on the location in the barn (Fig. 2.12). The frequency peaked at Period 2 (Period 1 vs. Period 2, P = 0.012) and declined to Period 3 (Period 2 vs. Period 3, P = 0.009) in the litter area. Pairwise comparisons revealed no significant differences among periods in the slatted area.

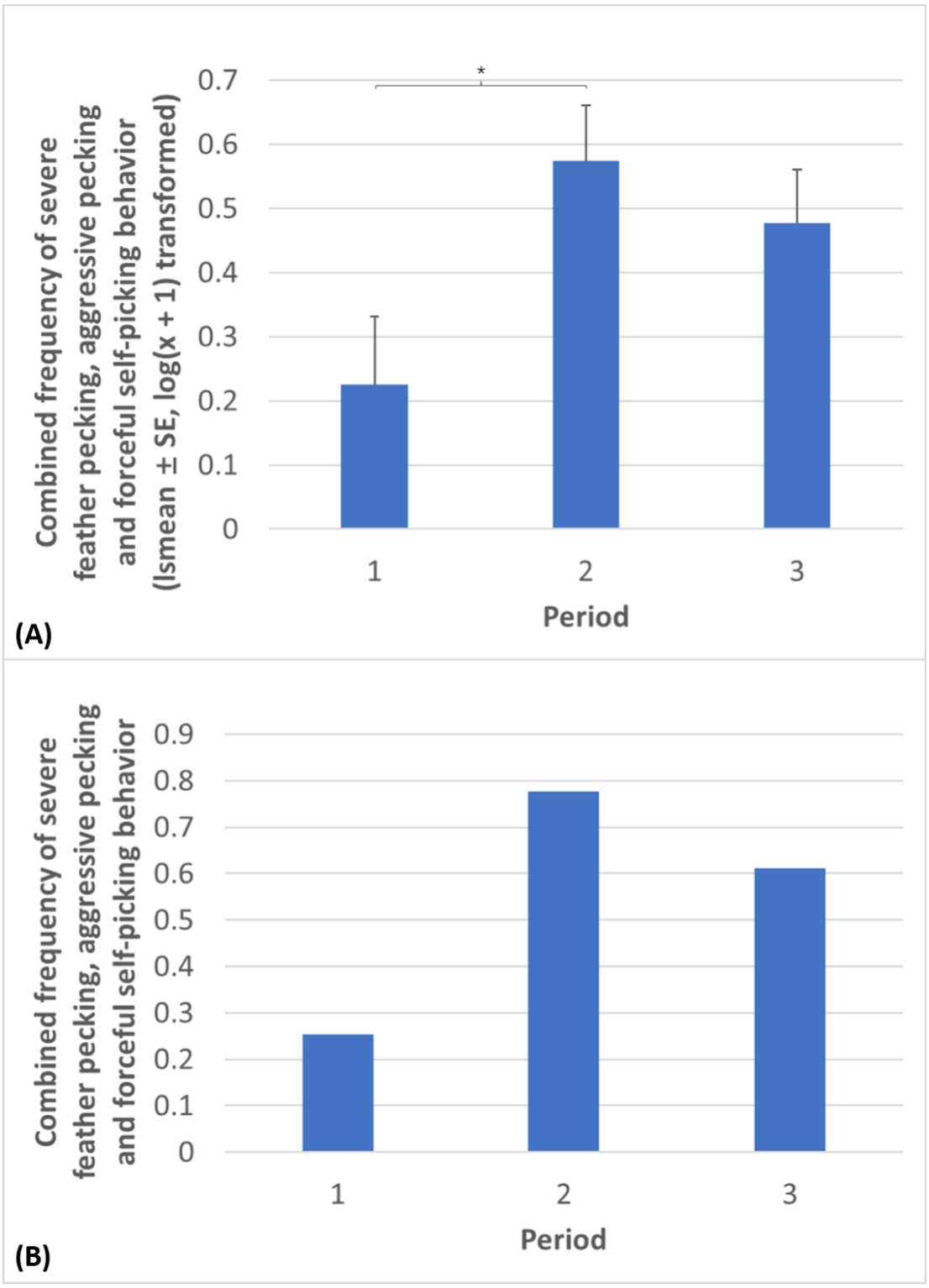

Figure 2.11. Combined frequency of SFP, AGGP and SELFP occurring at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d). Log(x+1) transformed LSMeans ± SE are reported in (A) and back transformed LSMeans are reported in (B). *P < 0.05.

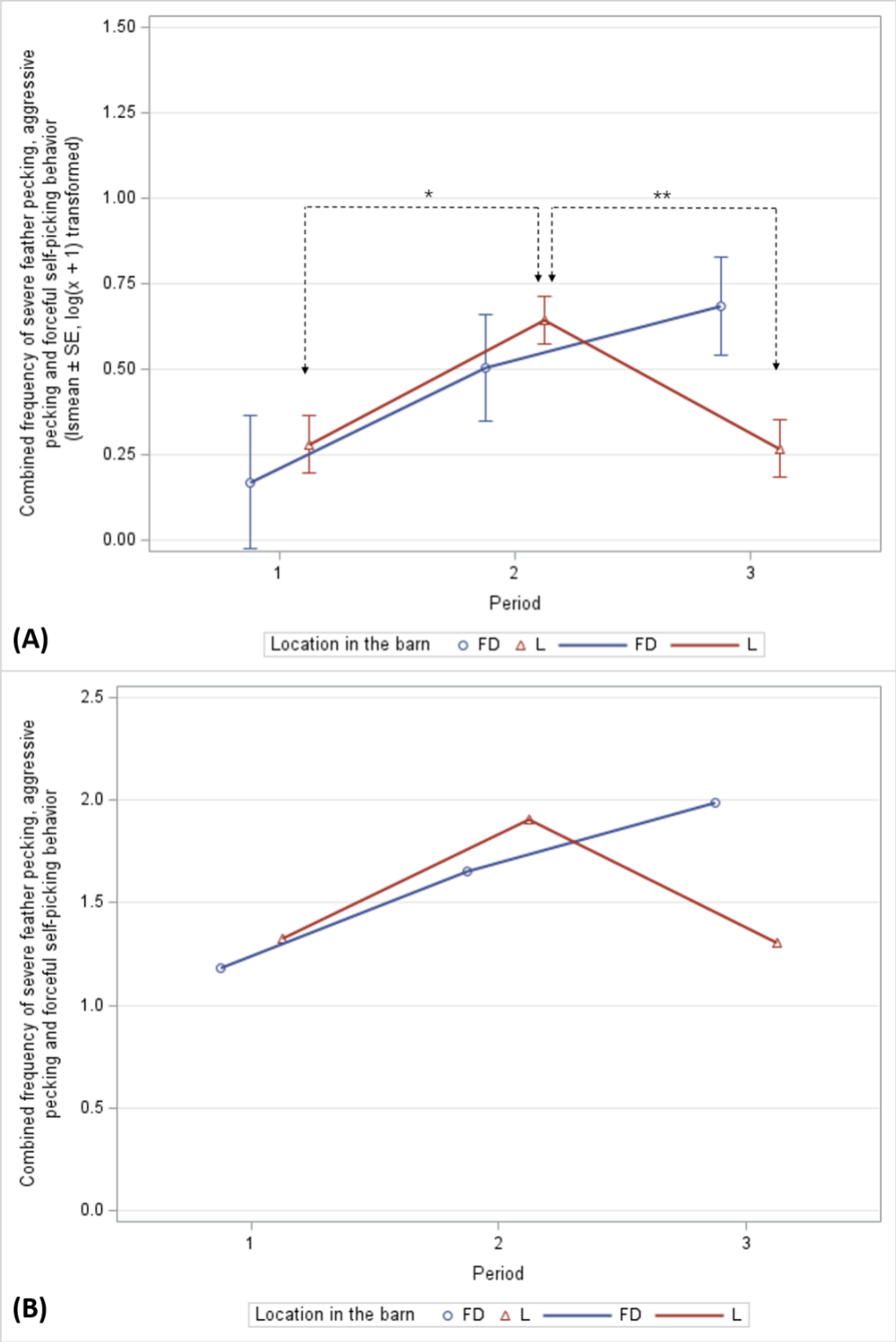

Figure 2.12. Combined frequency of SFP, AGGP and SELFP occurring at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d) and location in the barn (FD = slatted area, L = litter area). Log(x+1) transformed LSMeans ± SE are reported in (A) and back transformed LSMeans are reported in (B)* $P < 0.05$, ** $P < 0.01$.

Duration of preening

Preening duration was significantly influenced by age ($F_{2,277}$ = 14.27, P < 0.001), but not time of day ($F_{1,277}$ = 3.87, P = 0.05), location in the barn ($F_{1,277}$ = 0.01, P = 0.913) or any interaction effects (Age × time of day: $F_{2,277}$ = 1.33, P = 0.267; Location in the barn × time of day: $F_{1,277}$ = 1.54, P = 0.215; Age × location in the barn: $F_{2,277}$ = 0.07, P = 0.932). Preening duration peaked at Period 2 (Period 1 vs. Period 2, P = < 0.001) and declined to Period 3 (Period 2 vs. Period 3, P < 0.001; Fig. 2.13).

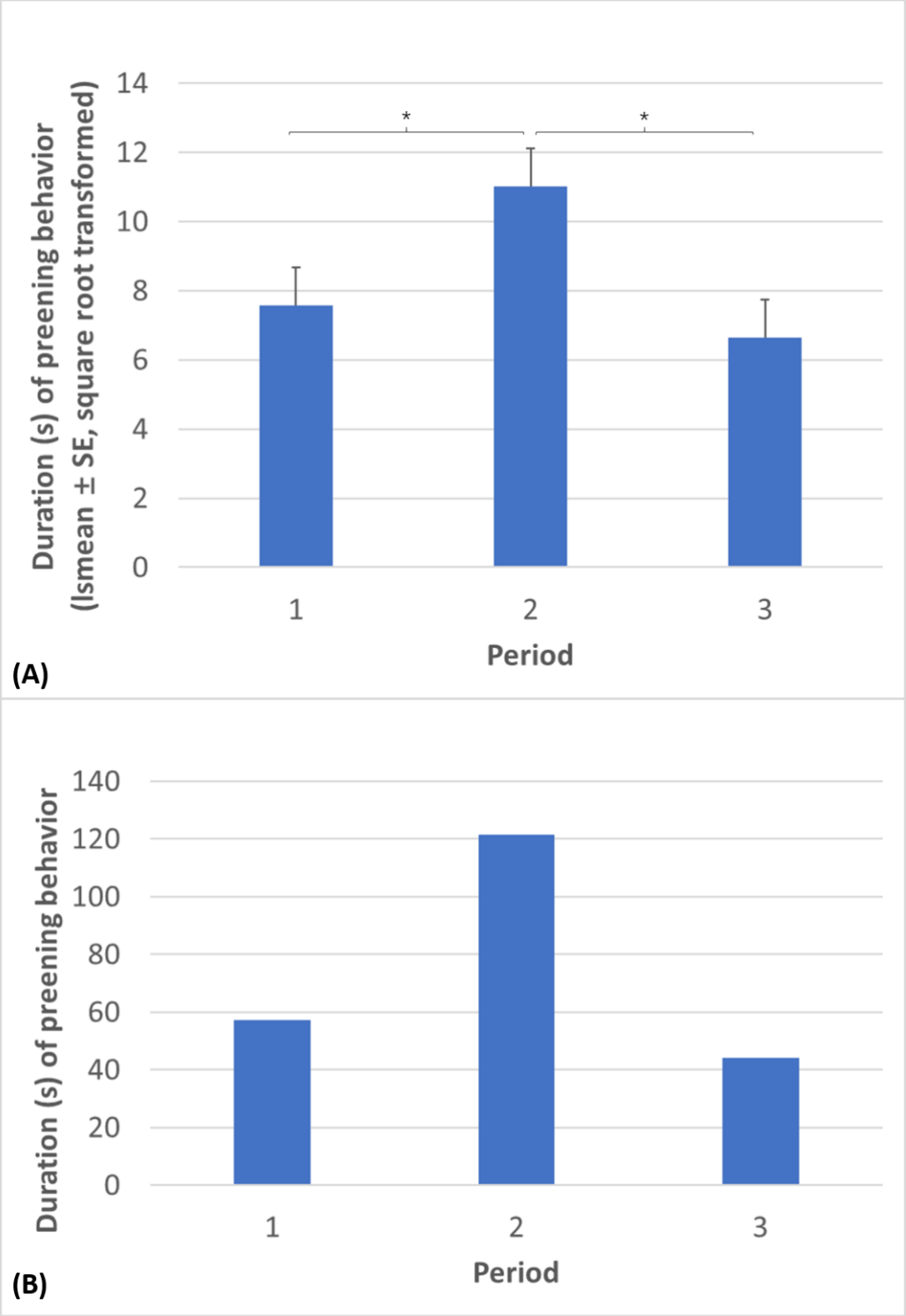

Figure 2.13. Duration of preening behavior occurring at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d). Square root transformed LSMeans ± SE are reported in (A) and back transformed LSMeans are reported in (B). * $P < 0.001$.

Duration of gentle feather pecking

Similar to preening duration, the duration of GFP was significantly influenced by age ($F_{2,277}$ = 41.55, P < 0.001), but not time of day ($F_{1,277}$ = 0.21, P = 0.649), location in the barn ($F_{1,277}$ = 0.42, P = 0.515) or interaction effects (Age × time of day: $F_{2,277}$ = 0.30, P = 0.745; Location in the barn × time of day: $F_{1,277}$ = 0.02, P = 0.899; Age × location in the barn: $F_{2,277}$ = 0.21, P = 0.809). GFP duration peaked at Period 2 (Period 1 vs. Period 2, P < 0.0001) and declined to Period 3 (Period 2 vs. Period 3, P < 0.001; Fig. 2.14).

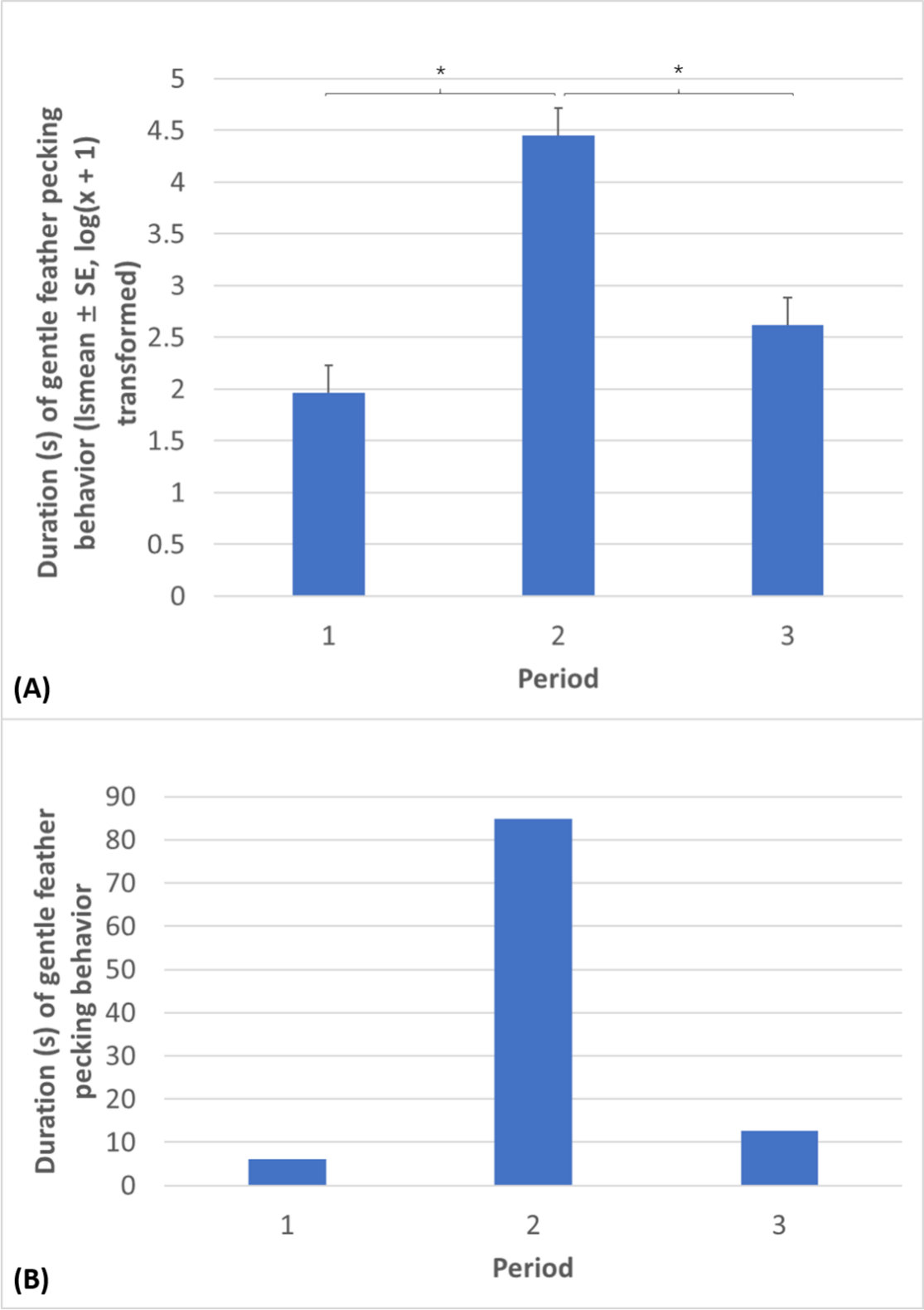

Figure 2.14. Duration of GFP (LSMean ± SE) occurring at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d). Log(x+1) transformed LSMeans ± SE are reported in (A) and back transformed LSMeans are reported in (B). * $P < 0.001$.

Duration of severe feather pecking, aggressive pecking and forceful self-picking

The combined duration of SFP, AGGP and SELFP was significantly influenced by age ($F_{2,277}$ = 3.37, P = 0.036), but not time of day ($F_{1,277}$ = 0.01, P = 0.91), location in the barn ($F_{1,277}$ = 0.02, P = 0.885) or interaction effects (Age × time of day: $F_{2,277}$ = 2.36, P = 0.096; Location in the barn × time of day: $F_{1,277}$ = 0.08, P = 0.784; Age × location in the barn: $F_{2,277}$ = 1.53, P = 0.219). The combined duration of SFP, AGGP and SELFP was significantly higher at Period 2 than Period 1 (P = 0.027) and did not differ between Period 2 and Period 3 or between Period 1 and Period 3 (Fig. 2.15).

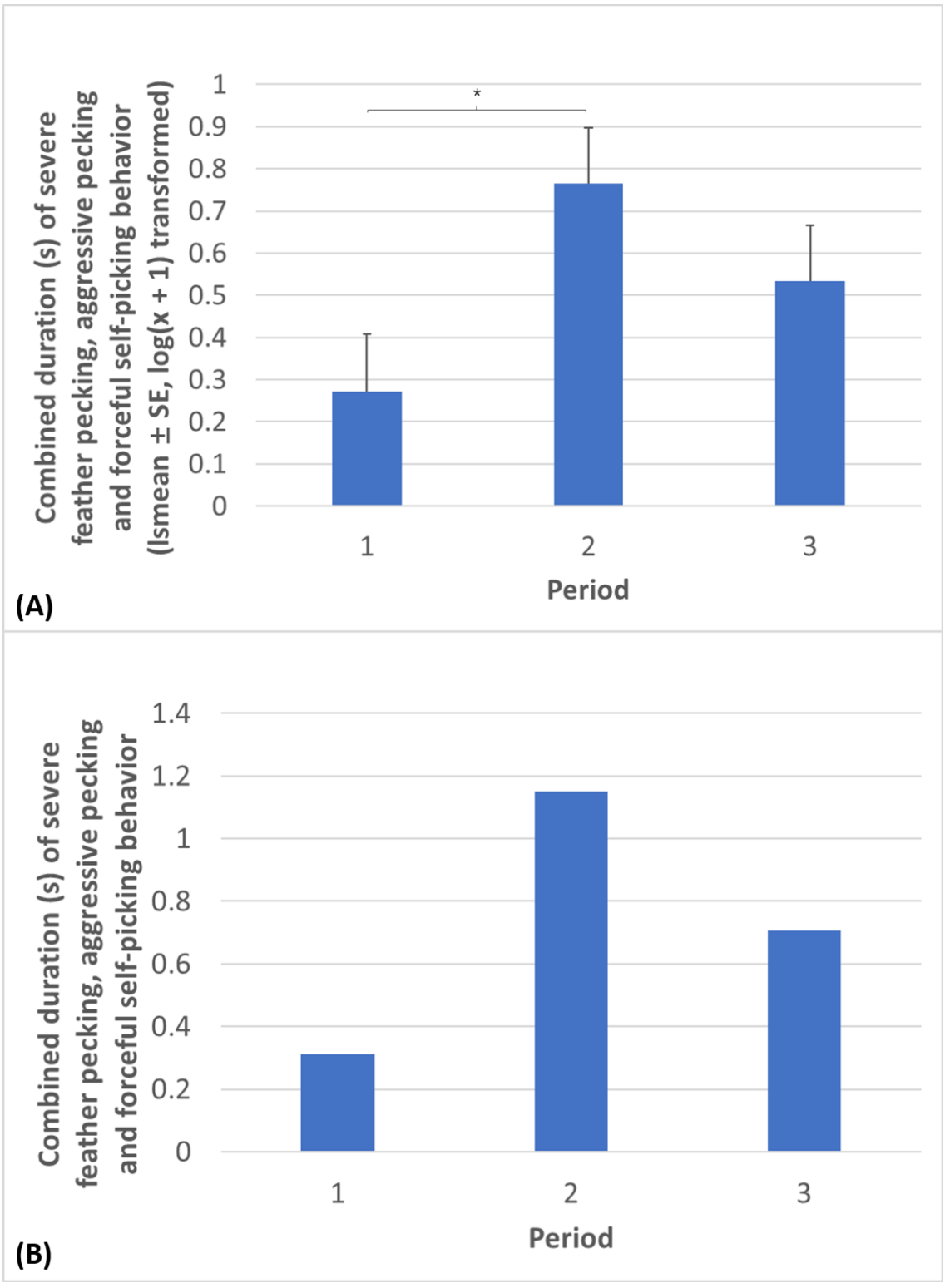

Figure 2.15. Combined duration of SFP, AGGP and SELFP (LSMean ± SE) occurring at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d). Log(x+1) transformed LSMeans ± SE are reported in (A) and back transformed LSMeans are reported in (B). * $P < 0.05$.

Descriptive characteristics of injurious pecking behavior

Body locations

The most frequently occurring injurious pecking behavior was GFP, which occurred 2403 times in total during the 6 days of video observation. The body locations pecked most frequently at Period 1 were quite different between the two flocks (Fig. 2.16). At Period 2 and Period 3, a similar pattern was observed for both flocks regarding the body locations pecked most frequently (Fig. 2.16). Other pecking behaviors were observed infrequently compared with GFP. SFP occurred 42 times in total during the 6 days of video observation of the 2 flocks. The body location pecked most frequently was the tail, followed by the wings. SFP was observed once on the breast and once on the head. AGGP was observed 59 times in total, most frequently directed at the head (but observed to be directed toward the neck and wing on one occasion). SELFP was observed 4 times in total and all instances were in the same flock. In Period 2, SELFP occurred once in the litter area and the pecked body location was the right wing. In Period 3, SELFP occurred once in the litter area (directed at the tail) and twice in the slatted area (also directed at the tail).

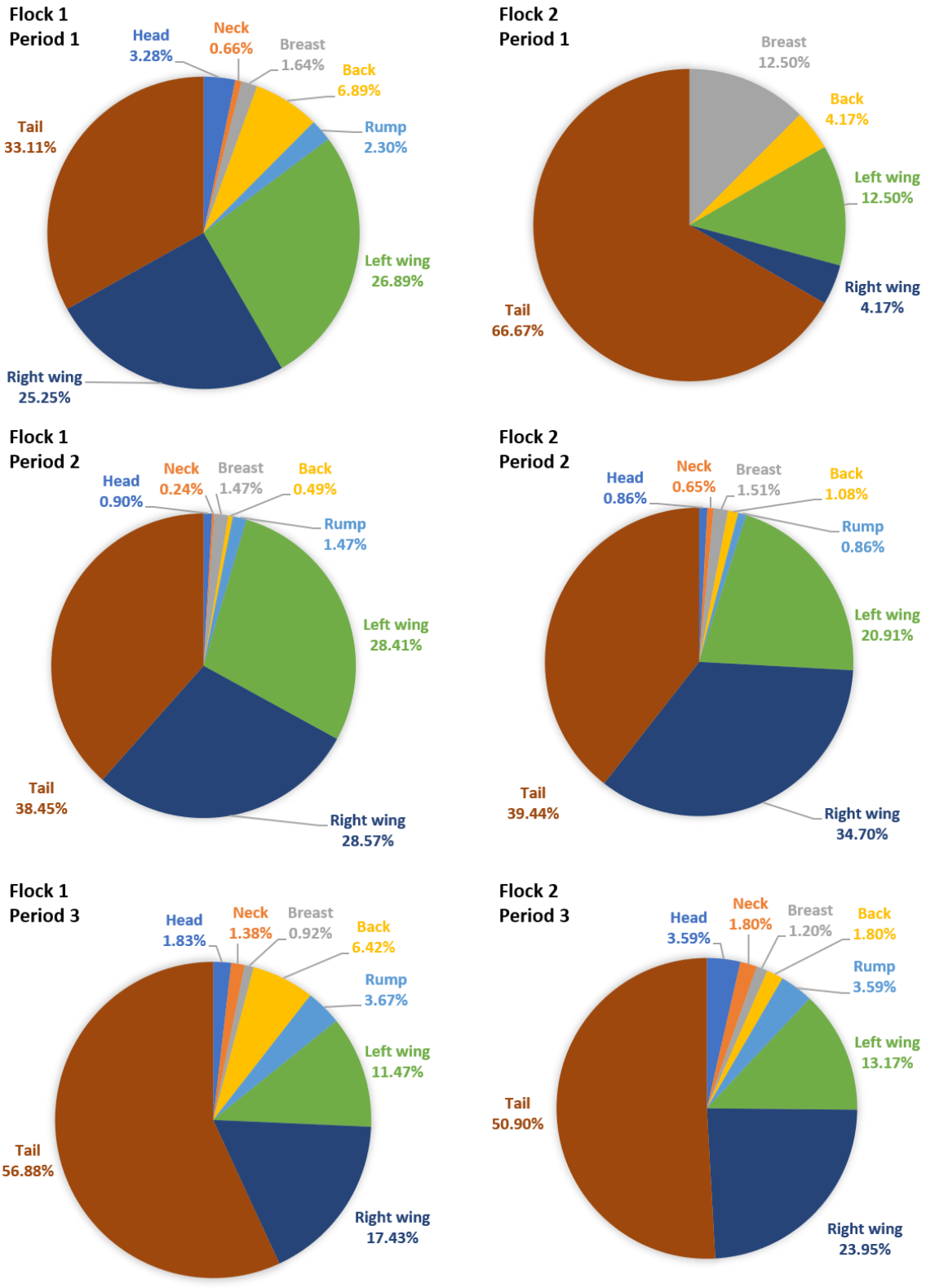

Figure 2.16. Percentage of GFP events directed at each body location at each age (Period 1 = 20-22 d, Period 2 = 27-29 d, Period 3 = 34-36 d).

The observed ducks' role in injurious pecking behavior

The percentages of ducks that were observed to peck, receive pecks, or both peck and receive pecks for each type of injurious pecking behavior are provided in Table 2.6.

Table 2.6. Percentage of ducks observed to peck, receive pecks or both peck and receive pecks for each type of injurious pecking behavior.

Behavior	Peck	Receive pecks	Both peck and receive
Gentle feather pecking (n=240)	14.17%	22.92%	62.92%
Severe feather pecking (n=40)	55%	40.0%	5.0%
Aggressive pecking (n=48)	39.58%	27.08%	33.33%
Forceful self-picking (n=4)	0	0	100%

Feather removal and feather eating

Removal of feathers was only observed 13 times during the 6 days of video observation. Feather removal occurred 5 times during GFP, 7 times during SFP, and 1 time during SELFP. There were only 7 times in all types of injurious pecking that a feather was eaten; 2 times during GFP and 5 times during SFP.

2.5 Discussion

Previous studies examined the welfare of Pekin ducks at different ages (Fraley et al., 2013; Karcher et al., 2013), but research to date had not examined the characteristics (percentage of ducks performing the behavior, duration and frequency of the behavior) or which body areas are affected by injurious pecking or picking. Moreover, previous studies either conducted brief observations of duck behavior (Colton and Fraley, 2014), or only examined feather damage (and not duck behavior) as an indicator of injurious pecking/picking (Fraley et al., 2013; Karcher et al., 2013). In this study, injurious pecking behavior was directly assessed through analysis of video recordings to provide more information about duck pecking behavior.

Both the welfare and injurious pecking behavior of the ducks were influenced by age, and less so by time of day and location in the barn (litter area vs. slatted area). Ducks' welfare condition worsened in Period 2 (29-30 d) and Period 3 (36-37 d). Previous studies had examined Pekin ducks'

welfare condition at 7-9 d (7 d), 20-24 d (21 d) and 30-33 d (32 d) (Fraley et al., 2013; Karcher et al., 2013) and examined Pekin ducks' behaviors by brief observations at 21 d (Colton and Fraley, 2014). When comparing welfare and behavior results in this study with those reported by previous studies, some differences and similarities were found. For welfare results, feather quality on all assessed body locations (except for the neck) worsened with age. Feather quality on the neck improved from Period 1 (17-18 d) to Period 2 (29-30 d), then worsened from Period 2 (29-30 d) to Period 3 (36-37 d). The overall feather quality result was in agreement with Karcher et al. (2013), who reported increased incidences of feather damage with age, but was not in agreement with Fraley et al. (2013), who reported no age-related difference in feather quality. Feather cleanliness on most assessed body locations was also affected by age, including cleanliness under the tail (worsened with age), rump cleanliness (better at Period 2 compared with Period 1 and 3), and breast and back cleanliness (worse at Period 3 compared with Period 1 and 2). Neck cleanliness did not differ among the 3 periods. The overall feather cleanliness result was in agreement with Fraley et al. (2013), who also found feather cleanliness was worse in older ducks but was not in agreement with Karcher et al. (2013), who found no age-related difference. Nostril cleanliness was affected by age with scores in Period 2 being statistically worse compared with Period 1 and Period 3, which was in agreement with both Karcher et al. (2013) and Fraley et al. (2013). Eye condition worsened with age, which was in agreement with Fraley et al. (2013) but was not in agreement with Karcher et al. (2013), who found no age-related difference. Footpad condition improved from Period 1 (17-18 d) to Period 2 (29-30 d), then worsened from Period 2 (29-30 d) to Period 3 (36-37 d), which was not in agreement with either Fraley et al. (2013) or Karcher et al. (2013), who reported that footpad condition improved with age. Gait was worse in Period 2 and 3 compared with Period 1, which was not in agreement with Karcher et al. (2013), who reported no difference across ages, while Fraley et al. (2013) did not assess gait. For behavior results, GFP was the most frequently observed pecking behavior, which was not in agreement with Colton and Fraley (2014) where the authors reported Pekin ducks mostly performed self-picking.

The proportion of ducks performing GFP, and the frequency and duration of GFP increased from Period 1 (20-22 d) to Period 2 (27-29 d), then declined from Period 2 (27-29 d) to Period 3 (34-36 d). The proportion of ducks performing GFP was higher in the morning than in the afternoon. Frequency and duration of preening behavior followed a similar age-related pattern to GFP. Frequency and duration of other injurious pecking behavior (SFP, AGGP and SELFP)

increased from Period 1 to Period 2, which was similar to both GFP and preening, but did not differ between Period 2 and Period 3. The body locations injurious pecking was most frequently directed at were the tail, wings and back. The body locations pecked most frequently at Period 1 were quite different between the two flocks, while a similar pattern was observed for both flocks at Period 2 and 3. Feather removal and feather eating occurred infrequently across the 3 periods.

The differences in results reported by previous studies and this study might be related to the differences of management and environmental conditions as well as methodological differences, including differences in farm geographic location, management and barn environmental conditions, as well as seasonal differences. Feather quality was reported to differ between duck farms located in northeastern Indiana, northern Indiana and southern Wisconsin (Fraley et al., 2013). Different flooring substrates (pine or raised plastic flooring) were also reported to influence feather quality such that ducks reared on slats had worse feather quality than ducks on litter (Karcher et al., 2013). Seasonal factors may influence results as well, but both Fraley et al. (2013) and this study were conducted during the summer whereas the Karcher study (Karcher et al., 2013) was conducted in the winter. The difference in feather cleanliness compared to Karcher et al. (2013) might be related to these seasonal differences. The difference in footpad condition and gait compared with previous studies might be related to the type of litter, humidity, season (Shepherd and Fairchild, 2010), ambient temperature, litter moisture, atmospheric ammonia (Jones and Dawkins, 2010) and litter management (Karcher et al., 2013). Increased levels of humidity and ammonia were reported as possible factors leading to worse footpad condition, and worse gait was reported with increased temperature, litter moisture, and atmospheric ammonia concentrations in Pekin ducks (Jones and Dawkins, 2010). High temperatures can affect ducks' appetite and cardiovascular system, thus affecting their walking ability (Jones and Dawkins, 2010). Ammonia was reported to be correlated with increasing litter moisture, which can cause worse leg health. Although the exact mechanism of ammonia affecting ducks' walking ability is still unknown, respiratory problems might be a possible effect (Jones and Dawkins, 2010). In chickens, high ammonia concentrations can irritate their eyes and respiratory system and can depress food intake, which might affect leg health (Kristensen and Wathes, 2000; Homidan et al., 2003; Jones et al., 2005). Footpad condition and gait are associated; for chickens, the risk of gait problems increased as footpad condition worsened, and there was a higher risk of worse footpad condition when gait worsened (Opengart et al., 2018). Similar results were reported here, where worsening footpad condition and worsening gait were

observed concurrently. For behavior results, the different methods used for behavioral observations in previous study and in this study might cause the difference. Colton and Fraley (2014) observed self-picking and conspecific pecking by taking notes of the number of ducks performing self-picking or conspecific pecking behavior when an observer walked through the barns for a 1-h period at 21 d. In this study, the number of ducks performing injurious pecking behavior was observed using video recordings of 6 days between 0900 to 1500h at 30 min intervals across 3 ages. Injurious pecking behaviors of 288 focal animals were observed continuously for 30-min segments in the morning or in the afternoon. Other external factors including different flooring substrates (Rodenburg et al., 2005; Leipoldt, 1992) and seasonal factors (Colton and Fraley, 2014) might also be the possible factors influencing the incidence of feather pecking and self-picking in ducks. Further research will be needed to examine environmental and management factors that can influence the development of injurious pecking.

Similarities in feather cleanliness and eye condition among this study and that of Fraley et al. (2013) as well as the similar results of nostril cleanliness compared to both Karcher et al. (2013) and Fraley et al. (2013) may be due to use of nipple drinkers in all three studies. The type of drinker has previously been reported to affect feather cleanliness (Jones and Dawkins, 2010), eye condition and nostril cleanliness (Knierim et al, 2004; O'Driscoll and Broom, 2011).

In this study, the changes in feather quality of ducks from Period 1 to Period 3 was consistent with the behavioral results. Feather damage increased from Period 1 to Period 2, consistent with the increased frequency and duration of injurious pecking behaviors from Period 1 to Period 2. The increased feather damage from Period 2 to Period 3 might be related to the cumulative damage of injurious pecking behaviors, although the frequency and duration of injurious pecking behaviors declined from Period 2 to Period 3. Although GFP was the most frequently observed pecking behavior, which usually causes no or little damage, in previous studies of laying hens and red junglefowl, GFP was reported to be correlated with SFP; GFP may develop into SFP (Newberry et al., 2007; Chow and Hogan, 2005). Furthermore, the actual prevalence, frequency and duration of injurious pecking behaviors occurring in the commercial duck flocks used in this study might be underestimated due to the sampling methodology and time constraints associated observing larger numbers of ducks.

The proportion of ducks performing GFP was higher in the morning than in the afternoon, which might indicate diurnal variation in GFP in Pekin ducks. Previous studies with chickens

reported feather pecking occurred mostly in the afternoon (Preston, 1987; Kjaer, 2000; Ramadan and von Borell, 2008). Higher occurrence of feather pecking in chickens was assumed to be associated with increased activity levels in the afternoon (Vestergaard, 1982; Appleby et al., 1992; Channing et al., 2001). Some researchers linked feather pecking behavior with feeding behavior, which increases in the afternoon (Appleby et al., 1992; Hoffmeyer, 1969; Blokhuis, 1986). The opposite pattern in Pekin ducks might indicate GFP might not be related to similar factors as chickens. Seasonal factors might also be a factor because temperature in the afternoon during the summer was higher than in the morning in the barns with natural ventilation, which might affect ducks' appetite and cardiovascular system (Jones and Dawkins, 2010); thus influencing ducks' activity levels.

The similar age-related changes in frequencies and durations of injurious pecking behavior and preening behavior might indicate possible relationship between them and their possible association with feather development of Pekin ducks. Between 20 and 30 days of age, Pekin ducks transition from down to adult feathers, and experience feather growth on the wings (between 24 and 36 d), breast (between 20 and 36 d), back (starting at 30 d) and tail (between 21 and 35 d) (Cherry and Morris, 2008; Southwick, 1953), overlapping with the observation periods used in this study (Fig. 2.17). Increased levels of preening and the occurrence of self-picking behavior were reported in Pekin ducks during 17-22 days of age when the feathers transition from down to adult feathers (Colton and Fraley, 2014). Further studies will need to be done to test whether preening behavior and injurious pecking behavior are related, as well as whether both behaviors are associated with feather growth and development.

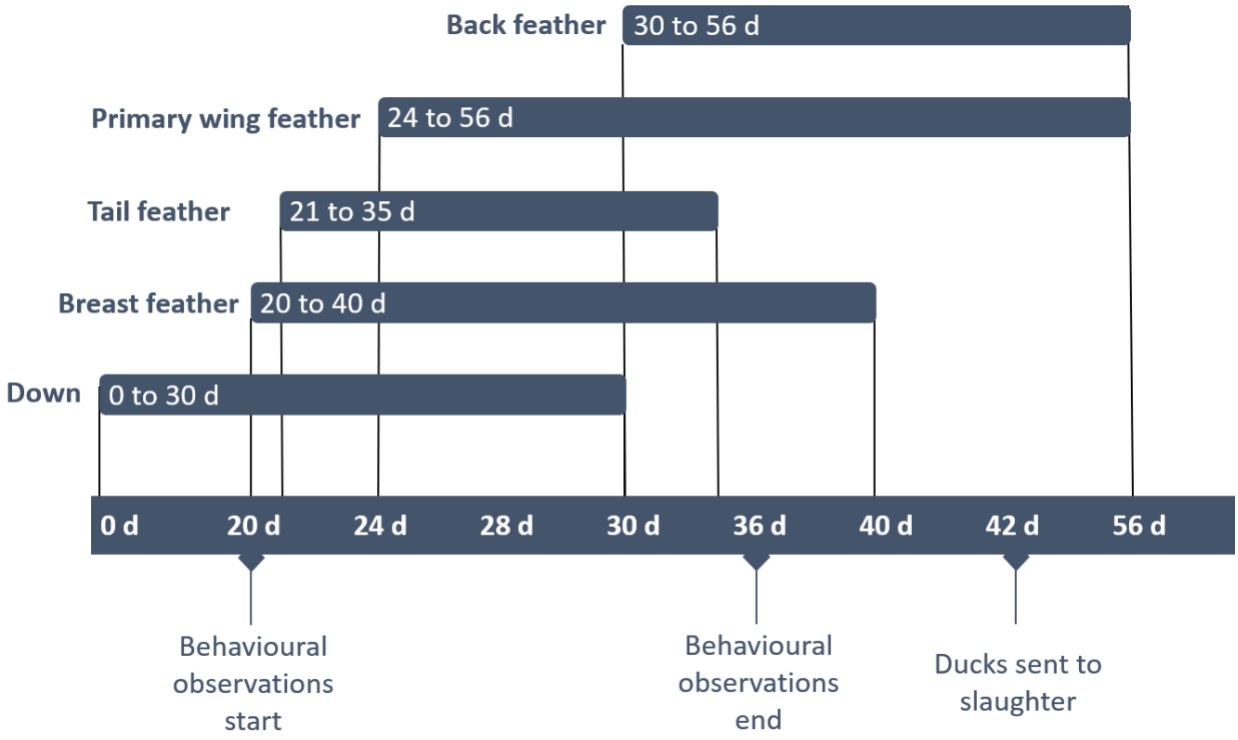

Figure 2.17. Relationship between age and relative down and feather growth of Pekin ducks.

The body locations of feather damage were also consistent with the behavioral observation results of injurious pecking behaviors. The body locations that were pecked most frequently were the tail, wings and back, which were consistent with the welfare assessment results. Most of the body locations of feather damage were consistent with the body locations experiencing feather growth (tail, wings and back), which supports a possible association between injurious pecking and Pekin duck's feather growth (Fig. 2.17). Age-related changes in neck feather quality were different from other body locations. Neck feather development is not discussed in Cherry and Morris (2008), but Southwick (1953) reported that feathering appeared on the head at about 4 weeks of age and spread down the neck in mallard ducks which is the species Pekin ducks originate from. Therefore, the later development of neck feathers relative to feathers on other body locations may provide some explanation for our results. Future studies will need to further investigate associations among feather development and injurious pecking of Pekin ducks.

Feather removal and feather eating were observed infrequently, which might indicate that injurious pecking behavior in Pekin ducks is not for the purpose of pulling out and eating the feathers. Previous studies in laying hens found the preference of eating feathers over fiber in high

feather pecking chickens (Bessei and Kjaer, 2015; Meyer et al., 2012; Meyer et al., 2013; Zhao et al., 2013). Difference in intestinal microbiota was reported in chickens presenting different levels of feather pecking (Bessei and Kjaer, 2015; Meyer et al., 2012; Meyer et al., 2013; Zhao et al., 2013). The primary motivation of feather pecking was hypothesized to be associated with feather eating, which may be caused by the specific microbiota in birds performing high level of feather pecking (Bessei and Kjaer, 2015; Meyer et al., 2012; Meyer et al., 2013; Zhao et al., 2013). Further research is needed to examine whether injurious pecking in Pekin ducks is related to dietary needs.

This study provided more details about the development and characteristics of injurious pecking behavior in commercial Pekin ducks. There are still unanswered questions including the specific causes of feather pecking and self-picking in Pekin ducks, whether feather development, preening and feather pecking /self-picking behavior are associated, and the environmental and management factors influencing the development and prevalence of injurious pecking.

CHAPTER 3. CONCLUSIONS AND FUTURE DIRECTIONS

The objectives of this study were to investigate the injurious pecking behavior in commercial Pekin ducks and provide more details about 1) the prevalence of injurious pecking behavior; 2) age-related changes in frequencies and durations of injurious pecking and preening behavior; 3) the body locations most frequently affected, and whether feather removal and feather eating occurred concurrently with injurious pecking; and 4) age-related changes in ducks' welfare that might be associated with injurious pecking.

In Chapter 2, welfare assessments and behavioral observations were conducted to study the injurious pecking behavior of commercial Pekin ducks. Both duck welfare and injurious pecking behavior were influenced by age, and less so by time of day and location in the barn (litter area vs. slatted area). Most welfare measures were worse in Period 2 (29-30 d) and Period 3 (36-37 d) than in Period 1 (17-18 d). Feather pecking between conspecifics was the most frequently performed pecking behavior, which peaked at Period 2 (27-29 d). The body locations most frequently affected included the tail, wings and back, consistent with the welfare assessment results. Feather removal and feather eating were infrequently observed. The frequency and duration of GFP and preening behavior changed similarly with age; however, further research is needed to evaluate whether these behaviors are associated and their possible association with feather development. There is still a lot to learn about injurious pecking behavior of Pekin ducks. The specific causes, influential factors and methods to reduce injurious pecking behavior will need to be studied in order to improve commercial Pekin ducks' welfare.

APPENDIX. EXTENSION BULLETIN

This extension bulletin has been published on the Purdue Education Store website: https://mdc.itap.purdue.edu/item.asp?Item_Number=AS-651-W.

An Explanation of Damaging Pecking Behavior in Poultry and Captive Birds

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Introduction

Injurious pecking is a major animal welfare concern for poultry and other captive birds. Injurious pecking includes feather pecking, cannibalism, and aggressive pecking. These behaviors may cause pain to the pecked bird, damage to the feathers and skin, and, in extreme cases, death. Feather loss caused by injurious pecking can affect the pecked bird's ability to maintain its body temperature, which leads to a need for more feed and increased economic costs. Production efficiency can be dramatically reduced, and birds that are pecked may experience increased levels of stress and fear. Table 1 summarizes the different types of injurious pecking and which species are more likely to perform each type.

Feather pecking and feather picking

Feather pecking and feather picking are often used interchangeably but they are not the same behavior. Feather pecking is mainly used to describe the behavior when a bird pecks and/or pulls at the feathers of other birds, which usually occurs in chickens, ducks, turkeys, pheasants, and quail. Feather picking is mainly used to describe a form of damaging behavior or auto-mutilation (self-harming) behavior where a bird is pecking at its own feathers, mostly in ducks and psittacine species such as parrots.

Feather pecking was first described in research as "damaging pecking" or "destructive pecking." There are two major forms of feather pecking: gentle and severe. Gentle feather pecking is usually directed at the tail, wings, back and neck of a bird. Gentle feather pecks are typically light and repeated without removal of the feathers. Severe feather pecking is mainly directed at the tail, back, vent and neck of a bird; severe feather pecks are usually hard, fast, and singular, with

pulling and sometimes removal of feathers. Contrary to what some people believe, feather pecking is an abnormal behavior that has not been linked to aggression and aggressive birds are no more likely to perform feather pecking than less aggressive birds.

Unlike feather pecking, feather picking is mainly used to describe a form of damaging, self-harming pecking behavior, specifically in psittacine species such as parrots. In captive parrots, feather picking behavior is exhibited when the parrot chews, bites and/or plucks its own feathers with its beak. Similar to feather pecking, feather picking can result in damage to the feathers and/or skin and may prevent normal regrowth of the feathers. Some scientists have proposed that feather picking in pet birds is a psychopathology that is analogous to trichotillomania (compulsive hair pulling) in humans. Feather picking also occurs in commercially-farmed Pekin ducks and is described and referred to as auto-mutilation (self-harming) behavior. In ducks, feather picking can begin when down feathers are lost and adult feathers begin to grow, which can then trigger feather pecking between conspecifics (birds of the same species).

Cannibalism

The relationship between feather pecking and cannibalism in poultry and captive birds is unclear. Sometimes, cannibalism occurs independently of feather pecking, and at other times cannibalism is preceded by feather pecking. Cannibalism can be categorized into two major types: tissue pecking and vent pecking. Tissue pecking can occur after severe feather pecking causes feather damage or feather loss, leading to bald patches of skin. Continued pecking of the exposed skin can then lead to cannibalism. Tissue pecking can eventually lead to the death of the pecked bird due to excessive blood loss and underlying tissue damage. Vent pecking, on the other hand, is specifically directed at the vent and the surrounding tissues of a recipient bird, and may begin as a form of investigatory pecking that can lead to death from loss of blood. Vent pecking may also continue as “pick-out,” in which organs such as the reproductive organs can be pulled out of the bird’s body.

Aggressive pecking

Although aggressive pecking is a form of injurious pecking, aggressive pecking is different than feather pecking because aggression is not believed to be a cause of feather pecking behavior. Many social species of animals establish a dominance hierarchy, or pecking order, to determine

when certain animals get access to resources such as food. Aggression is a normal part of establishing and maintaining the dominance hierarchy. However, in some situations aggressive pecking can become abnormally severe or occur more often than what is typical. Aggressive pecks are usually forceful and mainly directed at the recipient bird's head. This behavior is sometimes seen in groups of male turkeys and can be severe enough to lead to death.

Causes of injurious pecking in different species

Different theories have been proposed to explain why injurious pecking occurs, but the causes are not yet fully understood for many species.

1) Chickens

There are two main hypotheses about the cause of feather pecking in chickens: redirected dustbathing and redirected foraging. Birds in the wild spend a large amount of time foraging. Birds also spend time performing dustbathing behavior, which helps to maintain the condition of their feathers. When birds are housed in farm or captive environments, they are still motivated to perform these same behaviors, but the behaviors are directed at other birds instead of being directed at appropriate substrates.

According to the redirected dustbathing hypothesis, feather pecking in captivity is a modification of dustbathing behavior that typically occurs in the wild, such that some aspects of dustbathing are misdirected at the feathers of conspecifics when birds are not kept on suitable dustbathing substrate from an early age. Some research has demonstrated that birds that were raised with loose feathers as dustbathing substrate showed more feather pecking behavior than birds raised with sand. When a bird dustbathes, another bird may be attracted to the particles on that bird's feathers, or may be attracted to that bird because the feathers are ruffled or look different, which can also lead to feather pecking.

The redirected foraging hypothesis proposes that feather pecking is likely to be a form of ground pecking behavior derived from foraging that is redirected at other birds instead of being directed at the ground. In the wild, birds spend a lot of time foraging and scratching in order to find food. According to the redirected foraging hypothesis, laying hens develop feather pecking when they do not have access to a suitable foraging substrate, such as wood shavings, straw or dirt. A bird may be motivated to perform foraging behavior even when the bird has free access to food

and does not need to forage to find food. The lack of a suitable foraging substrate in combination with the shorter amount of time it takes to consume readily available feed contribute to the development of feather pecking behavior.

Some other causes of feather pecking include the genetic strain or breed of the bird. Some breeds or genetic lines of chickens are more likely to develop feather pecking than others. Feather pecking may also develop in birds that eat feathers on the floor and when there are no more feathers on the floor, these birds may then peck at feathers on birds.

2) Turkeys

Injurious pecking is a significant welfare concern for turkeys. It is a major cause of culls and mortality in adult turkeys. The specific causes of injurious pecking of turkeys, like that of laying hens, are unknown; however, injurious pecking in turkeys is considered to be related to redirected foraging. An environment that does not provide enough stimulation, together with turkeys' inherent tendency to peck, may result in both feather pecking and cannibalism. Other factors that contribute to the development of injurious pecking of turkeys include diet, environment and genetics.

3) Pheasants

There has been limited research into feather pecking of pheasants. Unlike other birds, the cause of feather pecking in pheasants is believed to be related to the feeding instinct. Some research demonstrated that feather pecking in pheasants sometimes starts as pecking related to feeding. Instead of pecking at food, however, pheasants peck at the feet, beak, cloaca and wings of their companions. Pheasants sometimes begin feather pecking when other birds in the group develop new feathers, and birds with new feather growth then become targets of pecking.

4) Quail

The two main forms of injurious pecking in quail include feather pecking and cannibalism. Like other poultry and captive birds, the causes of these behavioral problems are unclear. Research does not support the redirected foraging hypothesis as an explanation for feather pecking in Japanese quail, and there do not appear to be any studies investigating injurious pecking in other quail species. Some researchers have attempted to reduce feather pecking by providing quail with

environmental enrichment; however, results have been inconclusive, and some types of foraging materials actually increase pecking behavior. This indicates that the type of enrichment provided may be an important consideration for Japanese quail.

5) Ducks

Feather pecking and cannibalism are major problems in ducks, and again the causes are unclear. There are some differences among duck breeds in the type of injurious pecking behavior that is most frequently observed. In Pekin ducks, feather picking often leads to feather pecking between conspecifics around the time that down feathers are replaced by adult plumage.

Anecdotal reports suggest that feather picking and feather pecking follow a seasonal pattern, occurring more frequently in spring and fall. Unlike in Pekin ducks, cannibalism is a major issue for Muscovy ducks. This cannibalism in Muscovy ducks is not supported by the redirected foraging hypothesis, as it is in chickens. Thus far, research has found that outbreaks of cannibalism in Muscovy ducks can occur as early as 13 days of age and seem to be related to the appearance of new feathers.

6) Parrots

Feather picking behavior is a major problem in captive parrots, with no single cause or solution. Based on the research conducted to date, there are different theories and hypotheses proposed to explain why parrots pick their feathers.

a. Hormonal changes: This behavior often develops at the onset of sexual maturity and seasonal changes, and can be related to hormonal changes (e.g. changes in progesterone and estrogen levels).

b. Habitual or exaggerated behavior: Feather picking has been compared to habitual behavior, such as nail-biting in humans. Feather picking has also been compared to exaggerated grooming behavior that occurs because the amount of time that animals spend on various behaviors differs between animals in captivity and animals in the wild. Consequently, captive animals spend more time preening (or grooming) themselves, leading to exaggerated behavior. Sometimes, feather picking in parrots is inadvertently reinforced by well-meaning pet owners who give the parrot attention when the parrot is picking. The attention then serves to increase the likelihood of picking occurring again, because the bird is seeking the positive reinforcement of the attention.

c. Coping Strategy: Parrots may use feather picking behavior to cope with conditions that cause stress or boredom in captivity.

d. Redirect foraging hypothesis: Similar to other species, this hypothesis has been proposed as a possible underlying motivation for feather picking behavior in parrots.

e. Brain dysfunction: Some scientists believe that feather picking may arise as a result of brain dysfunction and changes in neurochemistry.

f. Reproductive behavior: Exaggerated or prolonged reproductive behavior in captivity has been proposed as another possible motivation for feather picking in parrots.

Preventing or reducing injurious pecking behavior

As demonstrated, injurious pecking in poultry and captive birds is affected by multiple factors. Strategies that can help prevent or control injurious pecking in some species of farmed or captive birds include proper feeding management and providing environmental enrichment.

1) Feeding management

The amount and form of the feed may influence the development of feather pecking. Dietary deficiencies result in a marginal supply of nutrients such as protein, amino acids, or minerals, and this may increase feather pecking behavior and cannibalism. For example, severe feather pecking has been found to occur in birds that were fed a diet too low in minerals; protein; or amino acids (methionine, arginine). Feather pecking occurs when birds are fed a diet with mainly vegetable protein sources. Birds that are restrict-fed sometimes develop feather pecking behavior as well.

In general, feather pecking behavior of laying hens seems to occur less frequently if the amount of time that hens spend foraging and consuming feed is increased. For example, research has shown that feeding hens high-fiber diets, low energy diets, or roughage that take longer to consume can reduce feather pecking. Providing additional grain or straw in the litter during rearing may reduce feather pecking behavior when birds mature.

2) Environmental enrichment

Environmental enrichments are often used to reduce injurious pecking by increasing the opportunities for captive animals to engage in foraging or/and exploratory behaviors. This provides

stimulation to animals that are unable to fulfill their inherent motivations due to environmental limitations.

a) Foraging and Dustbathing Enrichments: Because feather pecking is thought to be caused by redirected foraging motivation, providing forages to birds is likely to decrease feather pecking behavior in most poultry species. These forage enrichments are usually most effective at alleviating feather pecking, at least in the short term, and it is important to house birds in environments that allow them to perform foraging behavior. Other types of enrichment, such as providing material for dustbathing and novel (unfamiliar) objects, may be effective in reducing feather pecking; however, care should be taken when introducing novel objects because some objects can cause fear and stress instead of having a positive effect on the birds.

b) Spatial Configuration: Environmental enrichment can also include changing the spatial configuration of the birds' environment. Changing the space that the birds are kept in can impact the birds' perception, change how they use the space, and may influence their social dynamics. For example, chickens may use a larger area of their environment when provided with vertical barriers. Barriers can create more opportunities for birds to escape from individuals trying to perform injurious pecking behaviors, and they are more likely to use and perform comfort behaviors in areas with cover. Increasing vertical space by providing a hay bale or perches, for example, could provide a comforting space for chickens because they are naturally motivated to perch.

The known benefits of environmental enrichments include better ability to cope with challenging conditions, reduced occurrence of harmful behaviors such as severe feather pecking, decreased level

of negative affective state (e.g. fearfulness and depression), improved productivity and health, and enhanced behavioral repertoire. Some environmental enrichments allow the birds to perform behaviors they are strongly motivated to perform without harming their conspecifics. For example, string (that cannot be swallowed) has been shown to be effective in reducing feather pecking in hens. String devices fulfill at least some of the criteria (sustained interest, reduced expression of harmful behaviors) of effective environmental enrichment.

Summary

Injurious pecking is considered to be a major animal welfare and economic concern in poultry and other captive birds because injurious pecking may result in severe damage and death in some cases. In addition to experiencing pain, birds that are targets of injurious pecking may experience increased heat loss and require additional feed to maintain their body temperature. Production efficiency can be dramatically reduced, especially if high rates of pecking result in culling and mortality. Furthermore, birds that are the recipients of pecking may experience increased levels of stress and fear.

Injurious pecking takes different forms depending on the species of bird. Feather pecking is mainly used to describe the behavior when a bird pecks and/or pulls at the feathers of other birds, which usually occurs in chickens, ducks, turkeys, pheasants and quail. Feather picking is mainly used to describe a form of damaging behavior or auto-mutilation (self-harming) behavior where a bird is pecking at its own feathers, mostly in ducks and psittacine species such as parrots. Cannibalism (consumption of tissue or blood) sometimes occurs in chickens, turkeys, pheasants, quail and ducks.

Different theories have been proposed to explain why injurious pecking occurs, but for many species, the causes are not yet fully understood. What we do know is that injurious pecking is influenced by many different factors, such as environment, diet, neurobiology, early experience and management.

To prevent or reduce injurious pecking in poultry and captive birds, strategies such as proper feeding management and providing environmental enrichment can be helpful.

Table A.1. Description of injurious pecking behavior and the species of bird in which the behavior occurs

Term	**Definition/Description**	**Species in which occurs**
Feather pecking	A bird uses its beak to peck at the feathers of another bird. Can be categorized into two major forms: gentle feather pecking and severe feather pecking.	Chickens, turkeys, pheasants, quail, ducks
Gentle feather pecking	Pecks are usually light and repeated. They are mainly directed at the tail, wings, back and neck area of a bird.	Chickens, turkeys, pheasants, quail, ducks
Severe feather pecking	Pecks are usually hard, fast and singular. They are mainly directed at the tail, back, vent and neck area of a bird.	Chickens, turkeys, pheasants, quail, ducks
Feather picking	An auto-mutilation (self-harming) behavior. In parrots, it refers to a bird chewing, biting and/or plucking its own feathers with its beak.	Ducks, parrots
Aggressive pecking	Pecks are usually forceful and mainly directed at the recipient's head or other part of the body if the head area cannot be accessed.	Turkeys, chickens, quail
Cannibalism	Two types of cannibalism are recognized. Tissue pecking is directed at a bird's skin or tissue; vent pecking is directed at a bird's vent area.	Chickens, ducks, quail

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