EFFECTS OF ENVIRONMENTAL ENRICHMENT ON TURKEY BEHAVIOR, WELFARE AND WALKING ABILITY

by

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A Dissertation

Submitted to the Faculty of Purdue University

In Partial Fulfillment of the Requirements for the degree of

Doctor of Philosophy

Department of Animal Sciences

West Lafayette, Indiana

December 2022

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Dedicated to my family and friends for their endless love, support and encouragement

ACKNOWLEDGMENTS

Thank you to all the people who have made this work possible. In particular my major advisor Dr. Marisa Erasmus, who has led me to explore the field of animal behavior and welfare and has taught me so much on this path. Your guidance and advice helped me go through this challenging process. I really enjoy all the brainstorming and discussions we have, and I really enjoy the experience of working in your lab. Thank you for providing all the encouragement and opportunities for me to pursue this in the academic realm and beyond. Next, I would like to thank my committee members, Dr. Gregory Fraley, Dr. Janice Siegford and Dr. Fengqing Zhu for bringing different perspectives and providing a lot of valuable advice. Thank you for taking time from your busy schedule to meet with me and giving me all the helpful suggestions along the way.

Thank you so much to all the staff at Purdue Animal Sciences Research and Education Center (ASREC), for husbandry and assistance with my experiment set-up and data collection. Thanks to my lab mates, Hayley Sutherland, Hailee Yoder, Nathan Griffith for helping me with the experimental set-ups, data collections and providing a lot of helpful advice. Especially Hayley Sutherland, who is always helpful and reliable from building enrichments at the beginning to tearing down everything at the end of the experiment. Thank you for always being there for me.

I would like to acknowledge the help and work from Dr. Erasmus's lab undergraduates: Laura Zimmerman, Emma Nikolai, Jenna Boha, Abigail Sobczak, Ashley Edgar, Arianna Aguirre, Zoe Noble, and Teresa Carlson for helping me with building the enrichments, welfare assessments and helping with hours of videos.

Finally, I would like to thank my family and friends for encouraging and supporting me through this whole journey. Thanks for supporting me all the time. You are always there when I need advice or when my morale is low. You were good listeners when I was under pressure and were good teammates when I need help and advice.

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LIST OF ABBREVIATIONS

Abbreviations	Meaning
B	Pecking block
C	Control
EE	Environmental enrichment
FCON	Footpad condition
FQ	Feather quality
P	Platform
PS	Platform + straw bale
S	Straw bale
T	Tunnel

ABSTRACT

Injurious pecking, aggression, footpad dermatitis and leg abnormalities have been identified as major welfare issues in commercial turkey production, which lead to culling and mortality, downgraded carcass value and economic losses due to decreased productivity and carcass damage. Injurious pecking includes aggressive pecking (head pecking), feather pecking, and cannibalism. Aggressive pecking is related to aggression and is more prevalent in males than females. Feather pecking consists of non-damaging gentle feather pecking and severe feather pecking that can cause feather, skin and tissue damage, and even death in extreme cases. Common methods to control injurious pecking include infrared beak treatment and reduced light intensity, but those methods can result in inconsistent effects on feather condition and negative affect eye development. Footpad dermatitis and leg abnormalities can lead to lameness and an inability of turkeys to access feed and water.

Environmental enrichment, which is the modification of the environment of captive animals to improve their biological functioning, is one alternative way of reducing injurious pecking and potentially improving turkeys' walking ability. In meat-type poultry production, five types of environmental enrichment are usually used, which include social enrichment, occupational enrichment, physical enrichment, sensory enrichment and nutritional enrichment. For turkeys, some types of physical enrichment such as foraging and pecking enrichment have been found to be most effective in reducing injuries caused by injurious pecking and elevated structures (e.g. platform or straw bale) were effective in promoting locomotive exercise.

To address some of the gaps in the knowledge regarding the effects of environmental enrichment on turkey behavior, welfare and walking ability, this study examined 1) age-related changes in welfare and gait when turkeys are provided with different types of environmental enrichment; 2) the effects of different types of environmental enrichment on enrichment usage and injurious pecking behavior; 3) specific behaviors and relative location of turkeys when they interact with different types of environmental enrichment.

Data were collected from a total of 420 beak-trimmed tom turkeys housed in 24 littered pens located in two rooms within the same barn. Birds were randomly assigned to six treatment groups with 4 replicate pens per treatment group, including five enrichment groups (straw bale, platform, platform + straw bale, pecking block and tunnel) and a control group (no additional enrichment

provided). Welfare measures (wounds on the head, neck, snood, back and tail; beak abnormalities; feather quality; feather cleanliness; and footpad condition) and walking ability (gait) were assessed at 8, 12, 16 and 19 wk. Postmortem footpad condition was assessed at 19 wk. Behavior of turkeys was video recorded at 8, 12 and 16 wk and analyzed using scan sampling. The proportions of turkeys performing target behaviors were determined every 15 min (07:00 h - 22:00 h). Welfare and gait data were analyzed using PROC LOGISTIC with Firth bias-correction. Behavior data were analyzed using PROC GLIMMIX.

Better wing feather quality with age was observed in turkeys in the straw bale and tunnel groups. Footpad condition worsened with age for turkeys in all treatment groups except for the straw bale group. Gait worsened with age in all treatment groups while earlier onset of gait problem was observed in turkeys provided with a tunnel or no enrichment (control group). The average proportion of turkeys using the enrichments declined with age. Turkeys provided with a platform + straw bale had the highest levels of enrichment usage, followed by the platform group. Preening and severe feather pecking behavior did not change with age and were unaffected by the type of enrichment provided. Aggressive pecking and gentle feather pecking were not influenced by the type of enrichment provided. Higher average proportions of turkeys were observed performing environmental pecking in the control group than in the platform + straw bale group. Turkeys' usage of enrichments mainly included resting on top, locomotion, pecking and remaining under the enrichment when they had access to platforms; resting on top, locomotion and pecking when they had access to straw bales or pecking blocks; and remaining in the tunnel and pecking when they had access to a tunnel.

In conclusion, environmental enrichment showed beneficial effects on turkey wing feather quality, footpad condition and walking ability. Providing tom turkeys with straw bales and tunnels as environmental enrichment can help improve wing feather quality with age and providing straw bales may reduce the development of footpad dermatitis under suboptimal litter conditions. Providing enrichments that can help increase turkey activity and locomotion, including enrichment that can satisfy turkeys' pecking and foraging needs (straw bale or pecking block) and elevated structures (bale or platform), may be beneficial for turkey walking ability. Multi-functional environmental enrichments, especially a combination of enrichment objects, can promote turkeys' natural behaviors. Turkeys had the highest enrichment usage when provided with a combination of different enrichment objects (e.g., platform + straw bale) that can serve multiple functions to

fulfill their different behavioral needs. Providing a platform only can also achieve high enrichment usage. Turkeys gradually lost interest in interacting with enrichments over time, which may be associated with habituation, destruction of some enrichment objects (e.g. straw bale and pecking block) and fecal contamination on the surface of enrichments.

Future research will be valuable in examining the effects of different types of environmental enrichment in various commercial facilities and across different flocks and seasons. Research is needed to examine the effect of enrichments on turkey activity levels and whether there is a relationship between increased activity level and turkey walking ability. In addition, the effectiveness of making periodic changes to the enrichment objects and using unpredicted schedules of presenting the enrichments on habituation will need to be examined.

CHAPTER 1. LITERATURE REVIEW

1.1 Introduction

The domestic turkey (*Meleagris gallopavo domesticus*) is one of the common species of farmed meat birds worldwide. Over 2000 years ago, wild turkeys were domesticated in Mexico (Buss, 1989; Crawford, 1992; reviewed in Erasmus, 2018) and turkeys spread worldwide as domesticated birds since the 16th century (Brant, 1998). From the 16th to the 20th centuries, turkeys were mostly selected based on plumage and other characteristics for competition at shows and exhibitions. However, large and meaty turkey breeds became popular and spread quickly throughout the turkey industry starting from the early 20th century. Later, almost all commercially raised turkeys were selected to be white feathered based on consumer driven factors (Brant, 1998).

About 216.5 million turkeys were raised in the United States in 2021 (USDA, 2022), with Minnesota, North Carolina, Arkansas, and Indiana being the top four turkey producing states (USDA, 2022). In 2021, Americans consumed about 15.4 lb (6.99 kg) of turkey per person compared to 68.1 lb (30.89 kg) of chicken (USDA, 2022). Commercial turkey production consists of raising turkeys indoors on litter in either fully enclosed or curtain-sided barns (Duggan et al., 2014), which can hold up to 25,000 birds at stocking densities of up to 73.2 kg/m^2 (Buchwalder and Huber-Eicher, 2004; Erasmus, 2017). Turkey poults are initially brooded in a separate barn and provided with supplementary heat and then moved to the production barn at around 6 weeks of age (Aviagen Turkeys, 2015; Karcher and Mench, 2018). At 19 weeks of age, turkeys reach the average market weight of 32 lb (15 kg) (USDA, 2022).

1.2 Natural behaviors in wild turkeys and time budgets of domestic turkeys

1.2.1 Natural behaviors in wild turkeys

Locomotion

Wild turkeys spend most of their day on the ground and they usually walk slowly in their home range in search of food and water (Kuvlesky et al., 2020). Wild turkeys can also run fast when alarmed or when trying to get away from potential threats with speeds of up to 29 km/hr

(Kuvlesky et al., 2020; Mosby and Handley, 1943). In addition, wild turkeys are good at flying even with such a heavy and large body. They can fly continuously for up to a mile (1.6 km) with a speed of up to 97 km/hr (60 mile/hr) (Dickson 1992; Kuvlesky et al., 2020; Mosby and Handley, 1943). However, wild turkeys prefer ground activities except for flying up to roost in trees in the evening or escaping from threats because of the high energy expenditure of flying (Kuvlesky et al., 2020). For a full description of the behavioral ecology of wild turkeys, see Kuvlesky et al. (2020), Mosby and Handley (1943).

Foraging

Wild turkeys have a highly diverse diet based on the available food in the region they live. Wild turkeys mostly forage on the ground for seeds and occasionally on branches of shrubs or trees for fruits. They also eat bugs, small vertebrates (e.g. lizards) and various plant materials (e.g. leaves) (Kuvlesky et al., 2020; Mosby and Handley 1943). Wild turkeys constant peck at items that attract their attention (Mosby and Handley, 1943) and they also scratch and dig at the ground surface for mast and occasionally bulbs during spring, fall and winter (Kuvlesky et al., 2020). Foraging and feeding activities happen frequently in early morning and late afternoon, although they can happen any time during the daytime (Mosby and Handley 1943).

Roosting

Roosting is an important self-maintenance behavior in wild turkeys to avoid the threats from nocturnal predators. Wild turkeys usually roost at night on trees with relatively large lateral limbs and they normally roost on branches with a diameter of 2 to 4 inches (Kuvlesky et al., 2020; Mosby and Handley, 1943). Although modern turkeys in commercial production settings are generally housed in enclosed environments without predators, they still maintain some antipredator behaviors such as the preference for elevated space (Estevez, 2018).

Social behavior

Wild turkeys are extremely gregarious and they live in groups (Kuvlesky et al., 2020). Turkey poults initially remain with their mothers in the brood flock. Then juvenile males leave the brood flock and form the male flock called a sibling group. These sibling groups may attempt to

join adult male flocks consisting of older sibling groups. Female turkeys losing their juvenile males join other females to form larger female flocks (Watts, 1969). Wild turkeys have a strict dominance hierarchy or pecking order (Kuvlesky et al., 2020). In male turkeys, the dominance hierarchy is determined by the group of siblings (not necessarily genetically related but raised together and stay together for life) that fight other sibling groups (Kuvlesky et al., 2020). Fights between sibling groups mostly happen in late summer and fall. Each sibling group fights as a unit and moves up and down the flock hierarchy as a unit (Watts, 1969). The dominance relationships among siblings are determined by annual combat happening mostly in the fall and a linear hierarchy is formed for each sibling group. Fights within the sibling group often begin soon after daylight. After the fights, turkeys recover for several hours then reunite as a peaceful group by evening (Watts, 1969). Aggressive pecking is common when tom turkeys fight with other males to establish dominance or breeding access. Young turkeys learn aggressive pecking from adult birds as a fighting technique (Buchholz, 1997; Watts and Stockes, 1971; reviewed in Dalton et al., 2013).

1.2.2 Time budgets of domestic turkeys in indoor and free-range systems

Time budgets of domesticated turkeys in the confinement system (Table 1.1) and in the free-range system (Table 1.2) were studied by Irfan et al. (2016). Turkeys in the confinement system spent the highest percentage of time foraging from 4 to 20 wk, while free-range turkeys spent the highest percentage of time foraging at 4, 8 and 16 wk and highest percentage of time lying at 12 and 20 wk. Turkeys in the confinement system and the free-range system both spent a relatively large amount of time locomoting (walking or jumping), preening and lying.

Table 1.1. Time budget of turkeys (percentage of time spent for each behavior) in a confinement system at different ages (from Irfan et al., 2016)

Age (wk)	Aggressive pecking	Feather pecking	Preening	Locomotion (walking or jumping)	Standing	Lying	Feeding	Drinking	Foraging	Immobility
4	4.58	5.61	12.01	12.44	4.17	9.52	13.42	8.54	25.5	4.21
8	3.06	7.57	11.82	9.77	5.01	9.53	16.25	8.17	22.14	6.68
12	5.31	7.08	14.21	7.81	2.25	12.8	15.8	8.96	20.3	5.48
16	9.85	7.7	14.62	10.69	2.28	10.67	14.98	10.11	13.53	5.57
20	5	5.57	8.28	7.27	4.86	13.51	13.75	7.7	29.63	4.43

Table 1.2. Time budget of turkeys (percentage of time spent for each behavior) in a free-range system at different ages (from Irfan et al., 2016)

Age (wk)	Aggressive pecking	Feather pecking	Preening	Locomotion (walking or jumping)	Standing	Lying	Feeding	Drinking	Foraging	Immobility
4	5.92	5.55	14.84	16.19	10.77	15.39	8.74	5.7	14.89	2.01
8	1.97	5.83	16	16.06	9.94	16.55	7.61	5.64	18.17	2.23
12	5.67	4.63	15.26	13.99	8.7	18.25	9.64	4.27	17.51	2.08
16	6.55	6.23	10.17	16.12	9.08	11.95	10.63	5.73	21.49	2.05
20	8.27	5.19	16.58	16.36	7.48	20.39	6.01	4.42	13.07	2.23

1.3 Turkey welfare issues and current interventions

Good animal welfare has been acknowledged as one important factor for developing sustainable agriculture (FAO OIE WHO, 2010). In fact, the United Nations has recommended that improved animal welfare be considered a global goal in approaching sustainable agriculture (UN, 2016). As one of the major meat poultry species, welfare considerations of commercial turkey production from both researchers and the public have been increasing worldwide (Glatz and Rodda, 2013; Karcher and Mench, 2018). Welfare issues in commercial turkey production have been reviewed in recent papers (Erasmus, 2018; van Staaveren et al., 2020). Injurious pecking and aggression, footpad dermatitis and leg abnormalities have been identified as major welfare issues in turkey farming, resulting in increased culls and mortalities (Duggan et al., 2014; reviewed in Erasmus, 2018), downgraded carcass value and economic losses due to decreased productivity and carcass condemnations (Marchewka et al., 2013; reviewed in van Staaveren et al., 2020).

1.3.1 Injurious pecking and aggression

Injurious pecking is a common welfare issue affecting most commercial flocks, which consists of aggressive pecking (head pecking), feather pecking, and cannibalism (reviewed in Erasmus, 2018). Aggressive pecking is defined as pecks directed at the head, neck or snood of the turkey (Buchwalder and Huber-Eicher, 2003; reviewed in Erasmus, 2018), which is related to aggression and is more common in males than females (Dalton et al., 2013; reviewed in Erasmus, 2018). Feather pecking is defined as the pecking and pulling with or without feather removal, which consists of gentle feather pecking with little or no damage and severe feather pecking that can cause feather damage, skin and tissue damage, cannibalism and even death in extreme cases (Savory, 1995; Rodenburg et al., 2013; reviewed in Erasmus, 2018). Cannibalism is defined as skin and tissue pecking and consumption (Dalton et al., 2013; reviewed in Erasmus, 2018). Aggression toward conspecifics is mainly reported in male turkeys as a problematic issue, which can result in injuries and death (Buchwalder and Huber-Eicher, 2003; Buchwalder and Huber-Eicher, 2004; Dalton et al., 2013; reviewed in Erasmus, 2018). To control injurious pecking in commercial turkey production, infrared beak treatment and reduced light intensity are common methods (Erasmus, 2018). However, beak treatment showed inconsistent effects on feather condition (Struthers et al., 2022) and reduced light intensity may negatively affect eye

development and lead to vision issues and reduced activity levels (Nickla et al., 2001; Nicol et al., 2013; reviewed in Erasmus, 2018). Reduced activity levels can lead to, or be associated with, additional welfare issues including contact dermatitis, reduced drinking and feeding (Dawkins et al., 2017; de Jong et al., 2012; Haslam et al., 2007; Kyvsgaard et al., 2013; Olejnik et al., 2022) and reduced walking ability and lameness (Jacobs et al., 2023).

1.3.2 Footpad dermatitis and leg abnormalities

Footpad dermatitis and leg abnormalities can negatively affect walking ability, which may lead to additional welfare issues, such as becoming injurious pecking targets and having difficulty getting feed and water. These additional welfare issues may then cause reduced production efficiency and increased economic losses (Erasmus, 2018). Footpad dermatitis is the ulcerative condition of the footpad and the footpad may be swollen (Haslam et al., 2007; Mayne, 2005), which has been reported to impair the gait of the affected birds (Martrenchar et al., 2002). Footpad lesions can also be a potential entry for microorganisms and may cause secondary infection, which might lead to increased food safety risks and animal welfare concerns (Martrenchar et al., 2002; Shepherd and Fairchild, 2010). Leg problems in turkeys mainly include tibial dyschondroplasia (the appearance of abnormal cartilage masses at the proximal end of the tibia), valgus (hocks angled inside), varus (hocks angled outside), crooked toes, shaky legs and malformation of the legs, which can contribute to impaired walking ability and lameness (Erasmus, 2018; Hocking, 2014; Huang et al., 2017). Turkeys with lameness issues may have lower body weight and higher chances of downgrading at the slaughter plant, which can cause economic losses (Kestin et al., 1999). In a recent study, most turkey farmers reported leg abnormalities and leg injuries as the most common reason for culling (van Staaveren et al., 2020). Rapid weight gain and exacerbated growth of the breast muscle of commercial turkeys have been suggested to be some of the factors leading to leg problems and footpad dermatitis because of the increased area of surface in contact with the litter and the higher pressure exerted on the litter (Erasmus, 2018; Hester, 1994; Shepherd and Fairchild, 2010), which make those issues difficult to be prevented during production. However, a low to moderately positive genetic correlation between growth rate and some leg problems (e.g. valgus and varus deformities and crooked toes) were reported in recent studies, suggesting the possibility of simultaneous genetic selection for improved leg health and body weight (Hocking, 2014; Kapell et al., 2012). Environmental factors can also increase the

prevalence of footpad dermatitis and leg problems, including high temperature and humidity levels (Hester, 1994), wet litter (Da Costa et al., 2014; Youssef, et al., 2011), high ammonia levels from bacterial growth and urea in the litter (Haslam et al., 2007); these factors complicate the management and prevention of footpad dermatitis and leg abnormalities in commercial settings.

1.4 Environmental enrichment

One alternative way of reducing injurious pecking and improving walking ability is the use of environmental enrichment. Different animal welfare certification and assurance programs recommend the use of environmental enrichment, including Global Animal Partnership (G.A.P, 2020), American Humane Certified™ (American Humane, 2020), Certified Humane® (HFAC, 2014), and Farm Animal Care Training and Auditing (FACTA, 2016).

Environmental enrichment was first defined by Newberry (1995) as "an improvement in the biological functioning of captive animals resulting from modifications to their environment". The definition of environmental enrichment was later broadened by van de Weerd and Day (2009) into a framework of successful environmental enrichment, which includes four criteria: increasing species-specific behavior, maintaining or improve health of the animals, improving production efficiency and economic benefits, and practical to apply in the production system.

Environmental enrichments are usually designed to improve animal welfare and create more opportunities for animals to perform natural behaviors. The overall purpose of providing environmental enrichment was summarized by Newberry (1995) and Riber et al. (2018) as: (1) to prevent or reduce abnormal behaviors and improve physical health; (2) to reduce negative affective states and to increase the positive utilization of the environment; (3) to increase animals' ability to cope with behavioral and physiological challenges; and (4) to increase the occurrence and types of species-specific or natural behaviors.

1.4.1 Environmental enrichment implementation and effectiveness

The use of environmental enrichment is common in zoos and aquariums (Mellen and Sevenich MacPhee, 2001). The natural history of the animal species and the species-specific behaviors are important considerations when implementing enrichments in an optimal way (Fernandez and Martin, 2021; Mellen and Sevenich MacPhee, 2001). Three key aspects are

determined before the implementation of enrichments, including the goals of providing enrichments for the animal, the type of enrichments that will be implemented and how enrichments will be presented to maintain their effectiveness (Tarou and Bashaw, 2007). The goals of using enrichments in zoos consist of increasing an animal's behavioral repertoire and reducing problem behaviors (Fernandez and Martin, 2021). Based on the goals, enrichments are either provided to reinforce species-specific or desirable behaviors (e.g. exploration, foraging, hunting) or to reinforce another behavior that may be incompatible with the undesirable behavior (Novak et al., 1998; Tarou et al., 2003). The type of enrichment that will be provided is determined based on the desired behavioral change mentioned above and the considerations of the associations between the enrichments and the target behaviors (Tarou and Bashaw, 2007). How the enrichment is presented can directly affect the animal's response to the enrichment objects as well as its response strength and persistent interest in the enrichments.

To increase the effectiveness of enrichments, factors including reinforcement, habituation, preference, variation, and choice are usually considered for better implementation (Tarou and Bashaw, 2007; Woods et al., 2020; Hanratty and Hanley, 2021; Reviewed in Fernandez and Martin, 2021); these factors are further described below.

Reinforcement

Reinforcement consists of intrinsic reinforcement (the performance of a behavior itself increases the probability that the behavior will be performed again) and extrinsic reinforcement (the external consequence caused by performing a behavior increases the probability that the behavior will be performed again) (Hughes and Duncan, 1988; Tarou and Bashaw, 2007). Intrinsically reinforced behaviors include exploration, playing, nest-building, hunting, and stereotypic behaviors (Fagen, 1981; Hughes et al., 1989; Hughes and Duncan, 1988; Mason, 1991; Mench, 1998; reviewed in Tarou and Bashaw, 2007). Although quick and easy to implement, effects of intrinsically reinforcing enrichments are often short-lived and limited (Line et al., 1991, Renner et al., 2000, Vick et al., 2000; reviewed in Tarou and Bashaw, 2007). Extrinsic reinforcing enrichments generally show longer-lasting effects on animal behavior changes, as the external outcome (e.g. food) increases the probability of performing a behavior again (Tarou and Bashaw, 2007).

Habituation

Habituation is the reduction of response because of repeated stimulation (Harris, 1943). Intrinsically reinforced behaviors towards simple devices lead to habituation over time, resulting in a quick decrease in response to repeated presentations of these enrichments (Celli et al., 2003; Thompson and Spencer, 1966) and ineffectiveness in the long term (Line et al., 1991). Opposite to intrinsically reinforcing enrichments, the habituation of extrinsic reinforcing enrichments is suggested to be a result of habituation to the reinforcer (external outcome such as food) itself instead of the enrichment device (McSweeney et al., 1996; Murphy et al., 2003; Vick et al., 2000; reviewed in Tarou and Bashaw, 2007). A slower decrease in the response to extrinsic reinforcing enrichments happens when various reinforcers instead of identical reinforcers are available over time (Melville et al., 1997; McSweeney and Roll, 1998; reviewed in Tarou and Bashaw, 2007). Habituation can be influenced by generalization, dishabituation, frequency of stimulus presentation, stimulus strength and the characteristics of the stimulus (Murphy et al., 2003). Generalization refers to an animal habituating to both the enrichment device and other similar stimuli (Carlstead et al., 1991). Dishabituation is when the provision of new enrichment devices reduce habituation to the old stimuli and cause an animal to once more respond to the original enrichment devices (Carlstead et al., 1991). A higher frequency of stimulus presentation (e.g. enrichments left in the enclosure for extended periods of time or enrichments provided often in a short period of time) can cause faster and more pronounced habituation (Murphy et al., 2003). A weaker stimulus can cause faster and more pronounced habituation, whereas enrichments less similar to the enclosure can cause larger responses and slower habituation (Murphy et al., 2003; Powell, 1995). Stimuli presented at fixed or predictable intervals can cause faster and more pronounced habituation and changes to the original stimulus can disrupt the habituation to the enrichment device. Periodic changes to the enrichment and providing enrichments at unpredictable times of the day can help animals sustain interest to the enrichments (Bassett and Buchanan-Smith, 2007; Murphy et al., 2003). To reduce quick habituation to the enrichments, providing novelty to the environment consistently or rotating enrichments at irregular intervals are possible ways of enrichment implementation (Mellen and Shepherdson, 1997, Renner et al., 2000). Although habituation can cause decreased response to the enrichments, reduced animal interactions with enrichments over time is normal and even desirable, as we expect animals to engage with enrichments at levels similar to those expected in the wild (Tarou and Bashaw, 2007).

Preference, variation and choice

Providing enrichments that are species-appropriate and based on animal preference is crucial in enrichment implementation (Cooper and Mason, 2001). In addition, monitoring animals' interactions with enrichments and assessments of animal preference are important in enrichment implementation (Hoy et al., 2009). Preference assessment is a time and cost-effective way to consider enrichment objects as high-value reinforcers, which can provide longer duration of animal interactions with the enrichment and/or promote the most species-specific behaviors (Siegford, 2013; Woods et al., 2020). Variation and choice are parameters that can affect preferences. More variation and choices of reinforcers can possibly prevent satiation to single reinforcers and help slow the reduction of animal response to enrichments in a longer period of time (Hanratty and Hanley, 2021).

1.5 Environmental enrichment in meat-type poultry production

In meat-type poultry production, five categories of environmental enrichment are usually used according to the Guide for the Care and Use of Agricultural Animals in Research and Teaching (Ag Guide) (FASS, 2020) and Bloomsmith et al. (1991), which include social enrichment, occupational enrichment, physical enrichment, sensory enrichment, and nutritional enrichment.

1.5.1 Social enrichment

As described earlier, turkeys are social animals that live in social groups in the wild. For social species, social enrichment, which is defined as enrichment involving direct or indirect contact with conspecifics or humans (FASS, 2020), can be important if implemented appropriately. Social interaction and social learning are often beneficial to poultry, as socially isolated birds can suffer from distress (Jones and Williams, 1992; Johnston et al., 1998; Nicol, 2004) and social tolerance and resource sharing are commonly observed in both chickens and ducks (Jones and Dawkins, 2010; Makagon et al., 2011; Rice et al., 2014). Providing frequent exposure to kind and gentle handling (e.g. holding) and care can improve production efficiency and the immune response (Gross and Siegel, 1983; Jones, 1996), as well as reduce fear responses (Gross and Siegel, 1982; Nicol, 1992). In a study about fear responses of turkeys, turkeys with more human contact

showed reduced fearfulness of humans (Erasmus and Swanson, 2014). However, it is important to note that large flock sizes and high stocking densities often found in commercial turkey production can lead to social problems, including competition for feed and water and increased aggression (Estevez, 2018; Karcher and Mench, 2018). Therefore, the social environment should include appropriate amounts of resources, such as space, food and water, for socially-housed animals to be able to access these resources without causing increased competition.

1.5.2 Occupational and physical enrichment

Occupational enrichment is defined as psychological enrichment and enrichment that encourages exercise. Physical enrichment is defined as enrichment that adds accessories (e.g. objects, substrate, or permanent structures etc.) which alter the size or complexity of the environment (FASS, 2020). Occupational enrichment and physical enrichment often overlap with each other, such as elevated spaces and perches, covers and partitions, loose substrate, and objects.

In meat-type poultry, while perching behavior is rarely observed in broiler chickens and turkeys (LeVan et al., 2000; Martrenchar et al., 2001; Enneking et al., 2012), elevated structures that birds can balance themselves on, for example, platforms and low perches anchored to the ground, were more frequently used (Norring et al., 2016; Bailie et al., 2018; Ventura et al., 2012). Straw or hay bales can also be used as an elevated space as well as foraging substrate for broiler chickens and turkeys (Martrenchar et al., 2001; Vasdal et al., 2019). Modern turkeys used in commercial production still maintain some natural behaviors similar to their wild ancestors, such as roosting and locomotion. Turkeys' preference for elevated spaces can be linked to their roosting behavior in trees in the wild, which is a way to protect themselves from potential predator attacks (Estevez, 2018; Kuvlesky et al., 2020; Mosby and Handley, 1943). In addition, wild turkeys spend large amount of time locomoting. They spend most of their day walking in their home range mainly for searching food and water in the wild (Kuvlesky et al., 2020). Providing structures that encourage exercise can provide more opportunities for turkeys to fulfill their need of locomotion. There is also evidence that elevated structures and perches encourage vertical movement and exercise which can improve bone strength (Whitehead, 2004).

Other physical enrichments, such as vertical panels, can help improve space usage, increase resting and preening behavior, and decrease disturbances among chickens (Newberry and Shackleton, 1997; Cornetto et al., 2002; Leone and Estévez, 2008). Similarly, visual barriers were

shown to reduce pecking injuries in turkeys (Moinard et al., 2001) as they can help reduce encounters among the birds. Turkeys have a strict dominance hierarchy in the flock (Kuvlesky et al., 2020). Male turkeys in the wild not only fight with each other within the sibling group for their relative ranking but also fight as a unit for the dominant status in the flock when they encounter other sibling groups (Watts and Stokes, 1971). Aggressive pecking is used as a fighting technique in those fights (Buchholz, 1997; Watts and Stockes, 1971; reviewed in Dalton et al., 2013). Providing visual barriers can help avoid or reduce fights and reduce injuries caused by aggressive pecking.

As occupational enrichments, loose substrate can provide opportunities for birds to perform foraging and dustbathing behavior, and help reduce injurious pecking (Newberry, 2004; Rodenburg and Koene, 2004) and related feather damage (Tahamtani et al., 2016). In addition to promoting foraging behavior, providing broiler chickens with sand, peat, oat or rice hulls, straw pellets, and clean wood shavings can stimulate dustbathing behavior (Baxter et al., 2018a,b; Shields et al., 2004). Dustbathing improves feather condition and aids in the removal of ectoparasites (van Liere, 1992; Martin and Mullens, 2012; Vezzoli et al., 2015). There is limited research examining dustbathing in domestic turkeys; studies such as those by Sherwin and Kelland (1998) revealed that dustbathing occurred when wood shavings were replenished. The authors suggested that the characteristics of the litter may be a factor of eliciting dustbathing in turkeys. In terms of foraging behavior, wild turkeys spend a large amount of time engaged in foraging behavior (Mosby and Handley 1943), and domesticated turkeys can benefit from enrichments that promote foraging behavior.

Providing poultry with objects that can facilitate exploratory or pecking behavior can also reduce injurious pecking and aggressive behaviors. Improved feather quality was found in Pekin ducks provided with wiffle balls threaded with colored cable ties (Colton and Fraley, 2014). Providing straw or hay bales, and various pecking substrates (vegetable matter, rope, flexible plastic conduit and chains) were reported to reduced pecking injuries in turkeys (Sherwin et al., 1999a; Martrenchar et al., 2001).

1.5.3 Sensory enrichment

Sensory enrichment is defined as enrichment consisting of visual, auditory, or other stimuli (FASS, 2020). Sensory enrichment can be beneficial in improving poultry welfare. For example,

various forms of sensory stimuli (e.g. video, odors and music) may help reduce stress and fear responses toward novel environments in chickens (Jones, 2004). For turkeys, research examining sensory enrichment has mostly focused on the influence of different light sources and one study has examined the use of feeding calls. Turkeys are visually sensitive to ultraviolet (UV) radiation (Lewis et al., 2000). UV reflection may affect foraging in turkeys as it may be used to detect food items such as seeds and some fruit, which are highly reflective of UV under natural light and have strong contrast against the background (Burkhardt, 1982). Turkey feathers can reflect UV, which may play a role in individual recognition and maintenance of social hierarchies (Sherwin and Devereux, 1999). However, providing UV radiation as enrichment showed no effect on turkey welfare (Sherwin et al.,1999b), which might indicate that artificial light sources may not fully simulate natural sunlight and/or turkeys might be averse to artificial UV radiation (Moinard and Sherwin, 1999). The use of sound may be beneficial in improving turkey welfare. Wild turkeys use different vocalizations to communicate with each other for specific purposes and 28 distinct calls have been reported in wild turkeys (McRoberts et al., 2014; Williams, 1984). In one study, providing pre-taped maternal feeding calls was reported to enhance the initial feeding behavior in turkey poults (Alejandro Bate, 1992). Further research using the different vocalizations may provide insights into the use of sound, and in particular, pre-recorded turkey calls, for improving turkey welfare.

1.5.4 Nutritional enrichment

Nutritional enrichment is defined as changing the delivery method of food or providing various types of novel food (FASS, 2020). Scattering feed or other foraging substrates in the litter help increase birds' foraging time and frequency (Sherwin, 1995; Riber and Mench, 2008). Turkeys eat a wide range of types of food in the wild, including seeds, fruits, bugs, small vertebrates and plant materials (Kuvlesky et al., 2020; Mosby and Handley 1943). Wild turkeys spend several hours engaged in foraging and feeding activities during the day (Mosby and Handley 1943). Providing a variety of food or scatter food items may help fulfill the need of foraging behavior in turkeys.

1.6 Examples and applications of enrichments in meat-type poultry

1.6.1 Broiler chickens

The main categories of environmental enrichment for broiler chickens were reviewed by Riber et al. (2018), which include point-source objects in conventional environments, and more complex enriched environments. Enrichments provided in conventional environments include elevated resting places such as elevated platforms and perches, straw or wood shaving bales, panels, barriers, foraging or dustbathing substrate, and novel objects.

Offering elevated structures for perching is one of the approaches to enrich the housing environment of broiler chickens, which can help broilers perform their natural behavior of resting on elevated places (Collias and Collias, 1967; Sandilands et al., 2009). Perch access improves broilers' thermoregulation by providing opportunities to get away from the litter and get more air under their bodies (Estevez et al., 2002). In addition, reduced levels of aggression can be observed in broiler flocks with perch access (Ventura et al., 2012), and providing perches with multiple designs has been found to be more effective in reducing aggression (Pettit-Riley et al., 2002). Lower incidences of disturbance behaviors such as pushing and trampling (Buijs et al., 2010; Ventura et al., 2012), reduced prevalence of hock burns and footpad dermatitis, and improved feather cleanliness were observed in broiler flocks with perch access (Zhao et al., 2013). The raised platform (usually with a ramp) is an alternative method of providing elevated spaces in broiler housing. Improved leg health, indicated by better gait and lower incidence of tibial dyschondroplasia, can be observed in broilers with platform access (Kaukonen et al., 2016). Fast-growing broilers prefer platforms to perches because platforms are easier for heavy birds which cannot balance well on bars to access (Bailie and O'Connell, 2016). Platform has also shown to reduce fear level in fast-growing broilers according to a more recent study (Pedersen et al., 2017). The type of materials (wood, plastic or metal), and design of the structures (suspended bars, A-frame, and platform with or without ramps) influences the usage of the structures (LeVan et al., 2000). Structures with ramps or shallower angles to access are preferred options and platforms perform better than perches (Sandilands et al., 2016).

Straw or wood shaving bales is another type of point-source enrichment that can serve similar purposes as the elevated structures plus providing opportunities for broilers to perform explorative behaviors. Higher activity level and less sitting and resting were found in broilers

provided with straw bales (Kells et al, 2001). Fewer leg problems were found in broilers housed with straw bales. However, no scientific studies have examined the effects of other types of bales such as wood shavings, miscanthus, or silage which have been also used on commercial broiler chicken farms (Riber et al., 2018).

Panels and barriers increase the complexity in the broiler housing environment and help improve the homogeneity of the bird distribution. Providing panels in the center of the house increases the number of birds using the center of the house and reduce the number birds aggregate along the walls (Cornetto and Estevez, 2001a,b), as broilers usually prefer to stay along the walls in unenriched environments because of lack of cover or protection in the middle of the house (Arnould et al., 2001; Arnould and Faure, 2003; Buijs et al., 2010; Newberry and Hall, 1990; Newberry and Shackleton, 1997). Even panel frames without solid fills can attract broilers (Cornetto and Estevez, 2001b). As an alternative to panels, barriers are often lower but wider than panels, which may provide extra functions similar to elevated structures. Increased activity levels, reduced incidences of aggression and disturbances, as well as less foot pad dermatitis can be observed in broilers provided with barriers (Bizeray et al., 2002a; Ventura et al., 2010; Ventura et al., 2012).

Another point-source enrichment provided to broilers is foraging and/or dustbathing substrate. Providing sand may increase activity levels and reduce leg problems in broilers (Shields et al., 2004). A combination of sand and wood shavings can stimulate foraging behavior in broilers than birds housed with wood shavings only (Arnould et al., 2004). Broilers provided with moss-peat and oat husks have been found to perform highest activity levels and most dustbathing and foraging behavior in a study testing 5 different foraging and dustbathing substrates (Baxter and O'Connell, 2016). Other studies have investigated the effects of using novel methods of presenting feed to broilers on their activity levels. Scattering whole wheat or wood shavings has been found to have no effect on birds' locomotor or foraging activities (Jordan et al., 2011; Bizeray et al., 2002a; Pichova et al., 2016). Although scattering feed in the litter can increase foraging and locomotor behaviors, lower body weight was found in those birds (Jordan et al., 2011). Scattering meal worms in the bedding has also been tested but the effect was temporary and short-lasting (Pichova et al., 2016). Specific feeding systems would be needed in order to lengthen the effective time period of this type of enrichment (Pichova et al., 2016). However, some countries in the

European Union (EU) do not permit the use of insect protein in food producing animals (Commission Implementing Regulation (EU) No 836/2014).

Non-foraging novel objects have been examined for their effectiveness in increasing the complexity of broiler housing environments and reducing fear responses (Jones, 1996). Colored plastic balls, plastic bottles, toys, and mirrors have been provided to broilers and the results showed that providing suitable novel objects can reduce birds' fear response and increase their ability of coping with acute stressors (Altan et al., 2013). Reduced injuries and suffocation because of panic reactions to sudden or frightening events may be achieved using this enrichment but the feasibility of this approach needs more research and tests (Riber et al., 2018).

Apart from conventional point-source enrichments, more complex enriched environments fall into a different category of enrichments for broiler chickens. This category of enrichment includes housing systems with outdoor ranges, shelters and covers, and higher welfare indoor housing systems. However, limited research has been done in these enriched environments. Outdoor access may provide more space and opportunities for activities, and various weather conditions and sensory stimuli. But this system is usually used in organic production and not in commercial broiler production (Stadig et al. 2017). Providing shelters and covers (shade, shelter panels, and roosts) can increase the range of space used in the outdoor area and higher activity levels have also been found in birds housed with shelters and covers (Fanatico et al., 2016). Higher welfare indoor housing systems are defined as indoor systems with more stimuli such as perches, straw bales, pecking objects and natural light than conventional systems (de Jonge and Van Trijp, 2013; Gocsik et al., 2016). In addition, verandas (providing extra ranging space), and fibrous materials, roughage or sand (serving as foraging and dust bathing substrate) are also provided in these systems sometimes (de Jonge and Van Trijp, 2013; Gocsik et al., 2016).

1.6.2 Ducks

Limited studies have investigated the effects of environmental enrichment in meat ducks. Wiffle balls threaded with cable ties of different colors were provided as enrichment in commercial Pekin duck farms to test their effectiveness in reducing feather picking and improving body condition scores (Colton and Fraley, 2014). Their results suggested that Pekin ducks that interacted with enrichment showed reduced feather picking and improved body condition. In addition, ducks were found to have the preference for blue/green wiffle balls (Colton and Fraley, 2014). The effects

of environmental enrichment were also investigated in Muscovy ducks by Knierim et al. (2005) and Riber and Mench (2008). Water and foraging enrichments were tested for their effects on feather pecking and cannibalism (Knierim et al., 2005). Water basins, Astroturf mats with corn silage, baskets with straw automats, or twigs and corn were provided as enrichments and the results showed increased foraging and reduced injuries from feather pecking and cannibalism (Knierim et al., 2005). However, contrasting results were found by Riber and Mench (2008). This latter study examined the effects of water- and feed-based enrichment on ducks' activity patterns and the development of cannibalism. Water-based enrichments used in this study included a combination of water and plastic strings; water, plastic objects and gravel; water and grain mixture, or pure water only. Feed-based enrichments included a combination of corn silage, alfalfa, grain mixture and gravel, or a combination of Astroturf mats, grain mixture and occasionally mealworms. Their results showed that water- and feed-based enrichments had no effect on reducing injuries from cannibalism in Muscovy ducks, but foraging time was increased in enriched ducks and ducks were more active than the control group (Riber and Mench, 2008).

In summary, some occupational and physical enrichment including elevated structures, straw/wood shaving bales, panels/barriers and foraging/dustbathing substrate are effective in increasing broiler chickens' activity levels and reducing aggression, injuries, and leg and footpad problems. For ducks, some physical enrichment such as foraging and non-foraging pecking enrichment showed some positive influences, but the results are inconsistent among studies.

1.6.3 Turkeys

Applications of physical and occupational enrichment, and modifications to the environmental conditions (e.g. lighting) have been examined in turkeys. Several physical enrichments have been examined by Sherwin et al. (1999a) for their effectiveness in reducing pecking-related injuries and improving the welfare of male turkeys. A wooden board with attached crews, chains, hooks and ropes; flexible plastic conduit; Perspex boards with reflective aluminum foil in between; and cabbage were suspended in the pen as enrichments. Their results suggested that providing pecking enrichments help reduce pecking injuries and improve musculo-skeletal function of the birds. Sherwin et al. (1999b) also examined the effectiveness of different physical enrichment (foraging substrates and visual barriers) and sensory enrichment (lighting) in reducing injurious pecking behavior and pecking injuries in male turkeys. Wheat straw was provided as

foraging substrate, free-standing wooden boards were provided as visual barriers, and ultraviolet radiation (UV) was provided as a lighting treatment. Foraging substrates and visual barriers were found to help reduce wing and tail pecking injuries and no head pecking injuries occurred in turkeys provided with either foraging substrates or visual barriers, but UV radiation showed no effect on improving turkeys' welfare.

A broader range of environmental enrichments has been examined by Crowe and Forbes (1999) including different kinds of physical enrichment (loose straw and scattered grain as foraging substrate and hanging objects as non-foraging pecking enrichment) and occupational enrichment (perches). Their results showed that turkeys without enrichments had more injurious pecking than any enriched groups. Groups with perches and hanging objects had significantly less pecking than the control group. Turkeys preferred stimulatory objects which had a string-like appearance or was easily manipulated by the beak. Turkeys with straw and grain showed more pecking behavior than the object and perch groups as the small pieces may lead to increased competition within the groups. Martrenchar et al. (2001) further examined whether providing perches in addition to other physical enrichments (straw bales and reflective galvanized iron sheets hooked on metal chains) can reduce injurious pecking and provide opportunities for turkeys to perform roosting behavior. However, adding perches did not reduce pecking injuries as expected.

Apart from investigating the effects on behavior and welfare aspects, Huff et al. (2003) examined the effects of providing environmental enrichments during the early growing stage (2 wk) on modulating disease resistance of turkeys when challenged with *Escherichia coli* infection. Several physical enrichments were provided and rotated daily, which included commercially available infant toys, colored plastic balls, bells, mirrors, and other objects with textured surfaces. A T-maze procedure was used to divide birds into FAST and SLOW groups according to the time needed for the birds to complete the T-maze test. Based on previous chicken research, the FAST group had heavier body weights (Marin et al., 1999) and decreased adrenocortical responses to a stressor (Marin and Jones, 1999). Their results showed that groups of turkeys with enrichments and that were classified as FAST in the T-maze experienced higher mortality, more severe lesions of airsacculitis, and lower body weights than turkeys classified as SLOW. Turkeys without enrichments in the SLOW group showed better immune responses when challenged. The authors suggested that providing enrichments to turkeys during their early growing stage might have negative effect to turkeys in FAST group, and FAST turkeys may be more prone to bacterial

infection. However, it is possible that the use of these specific enrichments at this early an age increased fear and stress responses, rather than providing enriched environments as intended, because enrichments were changed daily, which also involved an observer entering the pen. Turkeys are known to be neophobic, and daily object changes may be more similar to introducing daily novel objects (which are used to examine fearfulness) that induce fear and stress responses, rather than providing enrichment per se.

The environmental changes that can help reduce injurious pecking in turkeys were reviewed by Dalton et al. (2013). Adjustments in lighting conditions (intensity, photoperiod, and light source) are some of the methods used to control injurious pecking. Commercial turkey production usually uses reduced light intensity (<10 Lux) to control the prevalence of feather pecking (Lewis et al., 1998a,b; Martrenchar et al., 2001). Providing fragmentary light periods (illumination provided in several non-continuous periods) throughout the day was another method used to lower incidences of injurious pecking and increase the performance of maintenance behaviors (e.g. feeding and drinking), which are highly motivated during the light period (Lewis et al., 1998b; Sherwin et al., 1999b). Modifying the light source, such as providing UV radiation in addition to incandescent lighting, showed inconsistent results based on previous studies. UV light was reported to help avert the initial development of injurious pecking in turkeys raised in a fully enclosed system (Moinard et al., 2001), and fewer tail and wing injuries were reported (Sherwin, 1999b; Moinard et al., 2001). However, a more recent study found that turkeys housed in an environment with natural UV light showed worse feather condition and increased mortality than birds housed without supplemental UV light (Duggan et al., 2011). Other modifications to the environment including different types of physical enrichment (straw bales, visual barriers and some types of novel objects) also helped reduce injurious pecking in turkeys (Sherwin et al., 1999b; Moinard et al., 2001; Martrenchar et al., 2001). However, a more recent study using colored plastic balls as enrichment found no difference in feather pecking behavior between enriched and control groups in large flocks of turkeys (Duggan et al., 2011). The authors suggested the plastic balls may be an ineffective stimulus as they were non-friable, and the long-time presence of the balls caused habituation and loss of interest for the turkeys (Duggan et al., 2014). More recently, Lindenwald et al. (2021) examined the effects of elevated platforms (“turkey tree”) on behavior, body weight development and immune parameters of female turkeys. The “turkey tree” was a 3-level platform structure designed to provide turkeys with resting areas and shelters. Lower prevalences of feather pecking

and fighting behaviors and better feather and integument condition were reported in the enriched group. However, no differences in body weight and humoral immunity were found between the enriched and the control group. In summary, some types of physical enrichment such as foraging and pecking enrichment are most effective in reducing injuries in turkeys according to previous studies. Additionally, elevated structures also beneficial in promoting locomotive exercise.

1.7 Current turkey welfare standards and use of enrichments on commercial turkey farms

Several animal welfare certification organizations have developed turkey welfare standards that list various types of acceptable environmental enrichments that can be used on commercial turkey farms. These organizations include Global Animal Partnership, Humane Farm Animal Care, American Humane and Farm Animal Care Training and Auditing. These welfare certification programs' standards are supported by previous research aimed at improving animal welfare in poultry production (Duncan et al., 2012; Souza and Molento, 2015), and many chicken producers are reported to participate in welfare certification programs (Brinkley et al., 2018). However, no information is currently available on how many turkey producers follow welfare certification programs or the current use of enrichments in practice on commercial turkey farms. The following provides a summary of each welfare certification organization's list of environmental enrichments for use on turkey farms.

Animal welfare certification organizations such as Global Animal Partnership's 5-Step® Animal Welfare Standards for Turkeys (G.A.P., 2020) provide guidance on environmental enrichments for turkeys in commercial production. The enrichments suggested in this guide are mainly focused on adding novel and stimulating accessories to the environment, which can raise and maintain turkeys' interest, improve their welfare and encourage them to perform natural and important behaviors, as well as reducing undesirable behaviors. Enrichments provided should not increase the risk of injury or distress. Some unacceptable enrichments are listed in this guide because of an inability to stimulate turkeys to engage in a wider range of natural behaviors, provide beneficial effects on birds' welfare or evoke and hold turkeys' interest. Unacceptable enrichments include non-edible hangers, perches, diatomaceous earth, music and radio, and required structures or materials already included in the production system (e.g. litter, feeders and drinkers). A list of primary and secondary acceptable enrichments is also provided. For turkeys up to 7 weeks of age, mini-ramps, sawdust piles and half barrels can be provided for birds to climb, balance, and rest.

For turkeys at all ages, straw or hay bales can be provided to facilitate locomotive activities, foraging and pecking behaviors, and roosting behavior. Edible hangers (e.g. suspending vegetables or grains) and pecking enhancements (e.g. hanging small bales) can be other options for pecking and foraging. Vertical structures (e.g. platform) can be provided to promote locomotive exercise of the turkeys. Increased locomotion can positively influence leg skeletal development in poultry (Lourenço da Silva et al., 2021; Reiter and Bessei, 2009; Ruiz-Feria et al., 2014) and increased locomotive exercise is beneficial for leg health and walking ability in turkeys (Hahn et al., 2020). However, increased locomotive exercise can lead to higher energy expenditure and heat production, which can cause poorer feed utilization and reduced feed conversion ratio (Clark et al., 2019; Morrison and Leeson, 1978). Except for the primary enrichments above, grains (e.g. loose grains or grain blocks) and forage bins, baskets and boxes can be provided as secondary enrichments to offer turkeys a novel way of foraging. In addition, visual barriers can be provided as a shelter for turkeys to hide and escape from their conspecifics. The Humane Farm Animal Care Standards for Turkeys recommend providing turkeys with environmental enrichments including hay or straw bales, perches appropriate to the size and weight of the birds, scattered grain and straw, hanging ropes at bird height, visual subdivision of the available space, and living vegetation (HFAC, 2014). Farm Animal Care Training and Auditing's turkey audit tool recommends providing occupational enrichment and physical enrichment to turkeys (FACTA, 2016). American Humane Certified™ Turkeys Animal Welfare Standards encourages providing appropriate environmental enrichments to turkeys such as hanging 'toys', short perches, alfalfa, or other vegetation (American Humane, 2020).

1.8 Environmental enrichment and poultry welfare: activity levels

Activity levels can be a welfare indicator in poultry. Decreased activity levels in poultry can often be associated with the occurrence of welfare issues such as footpad dermatitis and hock burn, reduced drinking and feeding behavior (Dawkins et al., 2017; de Jong et al., 2012; Haslam et al., 2007; Kyvsgaard et al., 2013; Olejnik et al., 2022) and reduced walking ability and lameness (Jacobs et al., 2023). A lack of environmental complexity can result in decreased activity levels and frustration of highly motivated behaviors in poultry (Kells et al., 2001; Vestergaard et al., 1997; reviewed in Baxter et al., 2019). Providing environmental enrichment to chickens can increase their activity levels, improve leg health and reduce fear responses (Kells et al., 2001; Reed et al.,

1993; Ventura et al., 2010; reviewed in Baxter et al., 2019). For example, straw bales, feed items (e.g., roughage, insects, mealworms) and dustbathing substrates can promotes foraging and/or dustbathing, leading to increased activity levels in broiler chickens (Bach et al., 2019; de Jong et al., 2021; Mocz et al., 2022; Pichova et al., 2016; Vasdal et al., 2019; reviewed in Jacobs et al., 2023). In addition, perches and elevated platforms can stimulate locomotor activity and exercise in broiler chickens (Jacobs et al., 2023; Riber et al., 2018). However, perches can increase the risk of keel bone damage in broilers (Bokkers and Koene, 2003; reviewed in Riber et al., 2018), and this needs to be considered when providing broiler chickens with perches. A combination of environmental enrichment was also reported to have positive effects on increasing activity levels in broilers, such as combining elevated platforms, straw bales, and laser light projections (da Silva et al., 2021; reviewed in Jacobs et al., 2023) and/or combining bales, perches and natural light from windows (Bailie et al. 2013; de Jong and Gunnink, 2019; reviewed in Jacobs et al., 2023). Research examining the effects of environmental enrichment on turkey activity levels is not available, but the previous studies with broiler chickens provide evidence that enrichments can increase activity levels. Since wild turkeys spend most of their time walking and foraging (Kuvlesky et al., 2020), providing enrichments that increase activity levels may benefit turkey health and welfare, but further research is needed.

1.9 Aims of this project

Previous studies have reported that providing some physical and occupational enrichments, such as foraging substrate, pecking objects, and elevated structures were beneficial to turkeys. Therefore, this study built on previous research and examined 1) age-related changes in welfare and gait when turkeys are provided with different types of environmental enrichment; 2) the effects of different types of environmental enrichment on enrichment usage and injurious pecking behavior; 3) specific behaviors and relative location of turkeys when they interact with different types of environmental enrichment.

CHAPTER 2. COMPARING DIFFERENT ENVIRONMENTAL ENRICHMENTS FOR IMPROVING THE WELFARE AND WALKING ABILITY OF MALE TURKEYS

A version of this chapter has been submitted for publication in PLOS ONE.

2.1 Abstract

This study investigated age-related changes in turkey welfare measures (wounds, feather quality (FQ), feather cleanliness, and footpad condition (FCON)) and walking ability (gait) as influenced by different types of environmental enrichment (EE). Tom turkeys (n = 420) were randomly assigned to: straw bale (S), platform (P), platform + straw bale (PS), pecking block (B), tunnel (T) or control (C; no enrichment) group. Welfare measures and gait were assessed at 8, 12, 16 and 19 wk and analyzed using PROC LOGISTIC with Firth bias-correction. Better wing FQ with age was observed in turkeys in S and T groups. Turkeys in the S group had better wing FQ at 16 ($P = 0.028$) and 19 wk ($P = 0.011$) vs. 8 wk. Wing FQ ($P = 0.008$) was better at 19 vs. 8 wk for T turkeys. FCON worsened over time for turkeys in all treatment groups except for the S group. FCON was worse at 19 vs.8 wk for P ($P = 0.024$), PS ($P = 0.039$), B ($P = 0.011$), T ($P = 0.004$) and C ($P = 0.014$) turkeys and was worse at 19 vs. 12 wk for B ($P = 0.038$), T ($P = 0.015$) and C ($P = 0.045$) turkeys. FCON was worse at 19 vs. 16 wk for T ($P = 0.007$) and C ($P = 0.048$) turkeys. FCON was also worse at 16 vs. 8 wk for B ($P = 0.046$) turkeys. Gait worsened with increasing age in all treatment groups. Gait was worse at 19 wk for S ($P < 0.001$), P ($P < 0.001$), PS ($P < 0.001$) and B turkeys ($P < 0.001$) vs. earlier ages, while gait in T ($P < 0.001$) and C turkeys ($P < 0.001$) worsened starting at 16 wk. In conclusion, providing tom turkeys with a straw bale and tunnel as EE can help improve wing FQ with age and providing straw bales may reduce the development of footpad dermatitis under suboptimal litter conditions. Providing EE that can help increase turkey activity and locomotion, including EE that can satisfy turkeys' pecking and foraging needs (straw bale or pecking block) and elevated structures (bale or platform), may be beneficial for turkey walking ability.

2.2 Introduction

Injurious pecking and leg health issues are among the major welfare and economic concerns of commercial turkey production. Injurious pecking among turkeys includes aggressive pecking (head pecking), feather pecking, and cannibalism. Aggressive pecking is particularly problematic in turkey toms and may lead to death in severe cases (Dalton et al., 2013). Severe feather pecking is a forceful pecking behavior that may involve removal and possible consumption of pulled feathers and leads to plumage damage and feather loss (Dalton et al., 2013; Erasmus, 2018). Cannibalism can develop independently or develop following severe feather pecking if bleeding occurs at the site of feather pecking, which may result in tissue damage and even death of pecked birds (Rodenburg et al., 2013). In addition to welfare issues, injurious pecking can lead to economic losses, such as those resulting from body heat loss and the resulting increased feed intake to maintain thermoregulation, thereby leading to reduced feed efficiency. Injurious pecking can also result in carcass damage and downgrading, as well as increased culling and mortality, which reduce production efficiency (Busayi et al., 2006; Duggan et al., 2014; Gilani et al., 2013).

Beak treatment is a common method of controlling injurious pecking in commercial turkey production (Jendral and Robinson, 2004). Hot-blade trimming was standard practice in the past and can cause both acute and chronic pain. Infrared beak treatment is currently used to remove turkeys' beak tissue without creating an open wound (Jendral and Robinson, 2004), and some studies have reported no evidence of pain or stress as indicated by beak-related behaviors and heterophil/lymphocyte ratios (Struthers et al., 2022). When examining feather damage associated with injurious pecking behavior, infrared beak treatment did not have a consistent effect on feather condition over a 12-wk period, with male sham-treated control birds having improved feather condition at 8 wk compared to beak-treated birds, while female infrared beak treated birds had better feather condition at 12 wk compared to controls (Struthers et al., 2022). Although it is common practice to treat turkeys' beaks immediately after hatch to reduce the severity of injurious pecking, feather pecking continues to be problematic.

In addition to injurious pecking, impaired walking ability (gait) and lameness are other major welfare problems that are consistently listed among the top ten health concerns of commercial turkeys (Clark and Froebel, 2020). Affected turkeys can suffer from pain, difficulty in accessing resources such as feed and water, and reduced ability to escape from their conspecifics because of impaired locomotor ability (Garner et al., 2002), which in turn can lead to these turkeys

becoming targets of injurious pecking. Turkeys with lameness issues may have lower body weights, resulting in economic losses (Kestin et al., 1999). Various factors contribute to gait impairment, such as rapid weight gain and breast muscle growth (Hester, 1994; Shepherd and Fairchild, 2010), environment (e.g. temperature and humidity) and management conditions, slippery flooring, diet, and photoperiod (Erasmus, 2018; Hester, 1994).

One possible method to reduce injurious pecking behavior and improve gait is to provide environmental enrichment. The use of environmental enrichment is becoming increasingly common as various animal welfare certification and assurance programs require the use of enrichment (e.g. Global Animal Partnership (G.A.P, 2020), American Humane Certified™ (American Humane, 2020), Certified Humane® (HFAC, 2014), and Farm Animal Care Training and Auditing (FACTA, 2016)); however, science on the effectiveness of environmental enrichment for turkeys is lacking. Studies with turkeys have either examined only the effects of environmental enrichment on the prevalence of injurious pecking behavior and pecking injuries (e.g. Sherwin et al. (1999b); Crowe and Forbes (1999); Martrenchar et al. (2001); Duggan et al. (2014)), or examined only one type of environmental enrichment (Sherwin et al. (1999a); Duggan et al., (2014); Lindenwald et al. (2021)). Only one study (Sherwin et al. (1999a)) examined the effects of environmental enrichment on both pecking related injuries and musculoskeletal function of turkeys, but this study was conducted over 20 years ago using a strain of turkeys that differs in growth rate and productivity from modern commercial turkeys.

While previous research has provided some insights into the effectiveness of environmental enrichment to reduce injurious pecking in turkeys, several key questions remain: (1) what are the effects of different types of environmental enrichment on turkey gait; and (2) how do welfare and gait change with age when turkeys are provided with different types of environmental enrichment. Therefore, the objective of this study was to investigate age-related changes in turkey welfare measures and gait as influenced by five different types of environmental enrichment.

2.3 Materials and Methods

2.3.1 Animals and housing

All procedures used in this study were approved by the Institutional Animal Care and Use Committee at Purdue University (PACUC 1904001883). A total of 420 beak-trimmed tom turkeys

(Nicolas Select, Aviagen Turkeys, Lewisburg, West Virginia, USA) were obtained from a commercial hatchery at 1 d of age and housed at the Purdue Animal Sciences Research and Education Center. From 1 to 11 d of age, the turkey poults were housed in 4 brooding rings with 105 birds per ring, and then randomly assigned to 24 littered (wood shavings) pens (measuring 3.05 m by 2.44 m) located in two rooms within the same barn with 16 to 18 birds per pen (stocking density 2.15 to 2.42 birds/m^2). Each pen was supplied with a hanging feeder and two bell drinkers, providing standard commercial feed and water ad libitum. Lighting and temperature were maintained according to standard industry practice (Aviagen Turkeys, 2015). For the first 24 hours, birds were provided with 24 h of light. Thereafter, lighting was adjusted to a final photoperiod of 16 h light and 8 h of darkness by the fourth day. A minimum light intensity of 40 lux was provided. Room temperature was reduced weekly according to the Aviagen guidelines (Aviagen Turkeys, 2015); birds were initially brooded at 30 °C, and thereafter the temperature was gradually decreased to a final temperature of 13 °C at 14 weeks. Turkeys were kept in their assigned pens until 19 wk when they were processed.

2.3.2 Environmental enrichment

Birds were randomly assigned to six treatment groups with 4 pens per treatment group, including five enrichment groups (straw bale, platform, platform + straw bale, pecking block and tunnel; Fig. 2.1) and a control group. Environmental enrichments were provided starting at 4 wk.

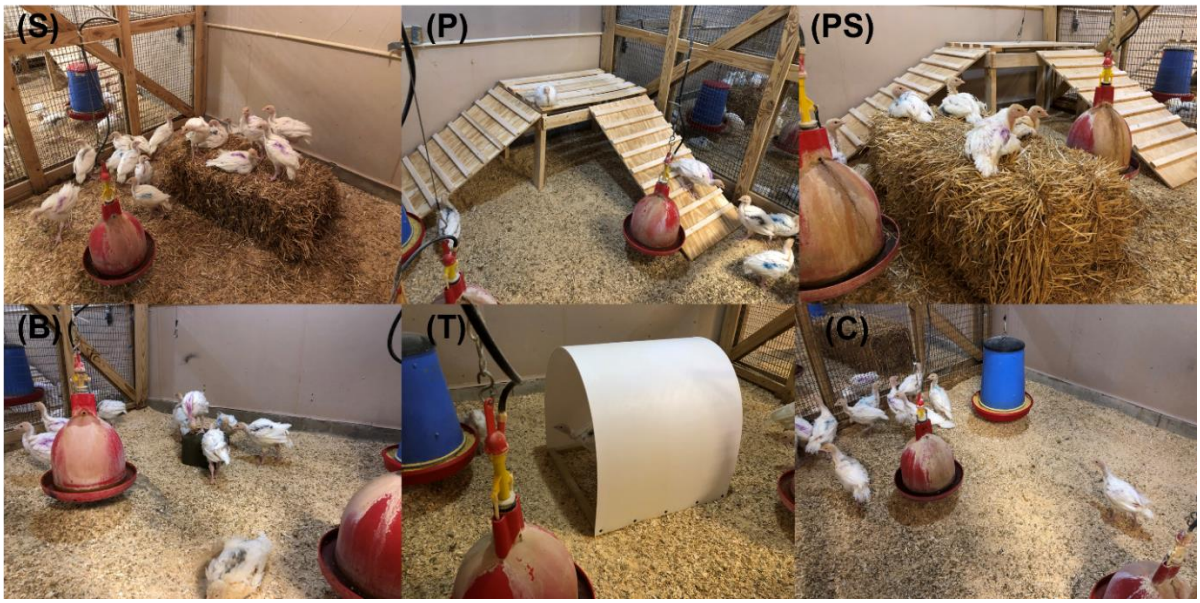

Figure 2.1. Depiction of the enrichment for each treatment group. S = straw bale, P = platform, PS = platform + straw bale, B = pecking block, T = tunnel, C = control.

Straw bale group (S): one straw bale (1.02 m length × 0.51 m width × 0.30 m height) was provided in the pen. Straw bales were replaced when the top of the bale collapsed and turkeys were no longer able to jump on the bale. Partially destroyed bales were assessed and replaced as necessary on a case-by-case basis. When replacing the bales, loose straw was also removed from the pen.

Platform group (P): one wooden platform with two ramps (overall size: 2.04 m length × 1.65 m width × 0.61 m height) was provided in the pen (platform size: 0.99 m length × 0.61 m width × 0.61 m height; ramp size: 1.22 m length × 0.61 m width, 30-degree angle relative to the ground).

Platform + straw bale group (PS): one wooden platform with two ramps (as described above) and one straw bale were provided in the pen. Straw bales were replaced using the same procedure as for the S group.

Pecking block group (B): one rectangular pecking block (0.23 m length × 0.23 m width × 0.18 m height) was provided in the pen (provided by Cargill Turkeys). New pecking blocks were placed into the pens when the old blocks were destroyed.

Tunnel group (T): one tunnel (0.61 m length x 0.61 m width x 0.58 m height) was provided in the pen. The tunnel was constructed of corrugated plastic sheets and a wood frame.

Control group (C): no enrichment was provided in the pen.

2.3.3 Welfare assessment

Turkeys' welfare status (wounds on head, neck, snood, back and tail; beak abnormalities; feather quality; feather cleanliness; and footpad condition) and body weight were assessed at 8, 12, 16 and 19 wk of age using a scoring system adapted from the AWIN turkey welfare assessment protocol (AWIN, 2015), Welfare Quality® Assessment Protocol for Poultry (Welfare Quality, 2009) and G.A.P.'s 5-step® Animal Welfare Standards for Turkeys (G.A.P, 2020) (Table 1). At 8 and 19 wk, welfare status and body weight were assessed and recorded for all turkeys. At 12 and 16 wk, half of the birds from each pen were randomly selected and assessed for welfare status and body weight (210 birds in total at 12 wk and 205 birds in total at 16 wk). Feather cleanliness of the wings and tail were added to assessments starting at 16 wk. Welfare measures were scored on a scale of 0 to 1 (feather cleanliness) or 0 to 2 (beak abnormalities, wounds, feather quality, footpad condition) where 0 was the best or ideal condition and a 1 or 2 indicated a worsening condition for that specific characteristic. For welfare and gait assessments, observers attended an on-farm training for scoring turkeys and scored the same birds before each assessment until consensus was reached, after which they continued to score turkeys independently.

Table 2.1. Turkey welfare scores and definitions (AWIN, 2015; G.A.P., 2020; Welfare Quality, 2009)

Condition	Score	Definition
Wounds	0	Best: No wounds present
	1	Moderate: < 3 fresh pecks or scratches present
	2	Worst: ≥ 3 fresh pecks or scratches present
Beak abnormalities	0	Best: No beak trim, no abnormalities present
	1	Moderate: Beak trimmed, with mild abnormalities
	2	Worst: Beak trimmed, with severe abnormalities
Feather quality	0	Best: No or slight wear, (nearly) complete feathering (only single feathers lacking).
	1	Moderate: < 50% of the feathers are damaged (worn, deformed) or one or more featherless areas < 5 cm in diameter at the largest extent.
	2	Worst: At least one featherless area ≥ 5 cm in diameter at the largest extent; or ≥ 50% of the feathers are damaged (worn, deformed).
Feather cleanliness	0	Clean: Clean and unstained down or feathers, or light discoloration of feathers from dust
	1	Dirty: Very clear and dark staining of the back, wing and/or tail feathers, not including light discoloration of feathers from dust, covering at least 50% of the body area
Footpad condition	0	Best: No lesion, no discoloration, no scars. Only mild hyperkeratosis
	1	Moderate: mild and/or superficial lesions. Visible hyperkeratosis (thickened skin). Superficial erosions, papillae. Discoloration of the footpad.
	2	Worst: severe and/or deep lesions. Ulcers and scabs.

2.3.4 Gait assessment

Turkeys' gait was examined at 8, 12, 16 and 19 wk of age. Gait was scored for a minimum of six steps taken in the home pen. Gait scores were determined using the 6-point system (0–5) developed by Kestin et al. (1992) and modified by Garner et al. (2002) and Vermette et al. (2016), where 0 represents no impairment in gait and 5 represents complete lameness. The detailed gait scoring system can be found in Table 2. After scoring the turkey's gait, both legs of the turkey (feet and toes) were examined and any abnormalities were recorded (Table 3).

Table 2.2. Descriptions of gait scores (Garner et al., 2002; Kestin et al., 1992; Vermette et al., 2016)

GS	Degree of impairment	Description
0	None	Straight legs. Smooth, fluid locomotion. The foot is furled while raised.
1	Detectable, but unidentifiable abnormality	The bird is unsteady, or wobbles when it walks. However, the problem leg cannot be identified in the first 20 s of observation. The bird readily runs from the observer in the pen. The foot may remain flat when raised, but the rest of the stride is fluid and appears unimpaired. Gait appears unstable (shaky or stomping).
2	Identifiable abnormality that has little impact on overall function	The leg producing the gait defect can be identified within 20 s of observation. However, the defect seems to have only a minor impact on biological function. The bird will run from the observer spontaneously or if touched or nudged. If the bird does not run at full speed, it runs, walks, or remains standing for at least 15 s after the observer in the pen has ceased to move towards or nudge it. Birds in this and previous scores are often observed to scratch their face with their feet, indicating little impact on function. (The most common abnormality in this score is for the bird to make short, quick, unsteady steps with one leg, where the foot remains flat during the step).
3	Identifiable abnormality that impairs function	Although the bird will move away from the observer when approached, touched, or nudged, it will not run, and squats within 15 s or less of the observer in the pen ceasing to approach or nudge it.
4	Severe impairment of function, but still capable of walking	The bird remains squatting when approached or nudged. This criterion is assessed by approaching the bird, and if it remains squatting, gently nudging or touching the animal for 5 s. Animals may appear to rise but still rest upon their hocks. Only rising to stand on both feet within 5 s of handling is counted. A bird that takes longer than 5 s to rise, or that does not rise at all, is scored as 4. Nevertheless, the bird can walk when picked up by the observer and placed in a standing position, but squats immediately following one or 2 steps (Squatting often involves a characteristic ungainly backwards fall). Bird requires wings for balance.
5	Complete lameness	The bird cannot walk, and instead may shuffle along on its hocks. It may attempt to stand when approached but is unable to do so, and when placed on feet unable to complete a step with one or both legs.

Table 2.3. Descriptions of foot and toe abnormalities (Ferket et al., 2009; Julian, 2005; Oviedo-Rondón et al., 2018)

Type	Abnormality	Description
1	Shaky legs	Legs are shaking or quivering when the turkey is standing
2	Joint swelling	The hock joint is swollen
3	Valgus	Hocks are turned inward
4	Varus	Hocks are turned outward
5	Curl toes	Toes are curled inward or outward
6	Other (describe)	Any other abnormalities

2.3.5 Postmortem footpad assessment

At 19 wk, a total of 144 birds (6 birds per pen) that represented the average body weight for birds in each pen were sent to the meat lab at Purdue university's Land O'Lakes, Inc. Center for Experiential Learning for processing. At processing, footpad dermatitis was scored on a scale of 0 to 2 using the same scoring system as described in Table 1 to provide another method for scoring footpads when turkeys were immobilized and footpads were potentially easier to observe.

2.4 Statistical Analysis

All statistical analyses were performed using SAS software Version 9.4 (SAS Institute Inc., Cary, NC). Beak abnormalities and back wounds were not analyzed statistically because all turkeys received a score of 1 for beak (all turkeys were beak-trimmed but had no additional abnormalities) and all turkeys received a score of 0 for back wounds at all time points examined. Differences among treatments and ages in welfare scores were analyzed using PROC LOGISTIC (SAS 9.4) with Firth bias-correction to correct for quasi-complete separation (Lu, 2016). Pen was considered as the experimental unit. Feather quality on the wings was analyzed as binomial data because all turkeys received a score of either 1 or 2 across all time points. Data were initially examined to assess the frequencies for each score, and based on this assessment, the remaining welfare scores, postmortem footpad scores, and gait scores were analyzed as binomial data to compare good vs. affected (score 0 vs score > 0) due to the low numbers of turkeys in score categories 1 and higher; i.e. scores above 0 were combined into one category for analysis because of the small number of observations with score > 0. Room was considered as a covariate in the models for welfare scores and gait analysis. No interaction effects were found. Results were reported as odds ratio estimates with 95% confidence limits (CL) (Kiernan, 2018).

2.5 Results

2.5.1 Welfare assessment

Influence of environmental enrichment and age

No back wounds or beak abnormalities (beyond trimming) were found across all observations in this study. All wing feather quality scores were found to be either a score of 1 or 2. Environmental enrichment significantly affected some turkey welfare measures, including feather quality on the neck (Wald χ^2 = 11.305 P = 0.046), coverts (Wald χ^2 = 30.27, P < 0.001) and wings (Wald χ^2 = 19.437, P = 0.002). Environmental enrichment also affected feather cleanliness on the neck (Wald χ^2 = 12.061, P = 0.034), back (Wald χ^2 = 14.328, P = 0.014), rump (Wald χ^2 = 26.815, P < 0.001), breast (Wald χ^2 = 27.384, P < 0.001), belly (Wald χ^2 = 23.54, P < 0.001), wings (Wald χ^2 = 13.988, P = 0.016), and tail (Wald χ^2 = 25.295, P < 0.001). Pairwise comparison results showed different patterns for the likelihood of having better welfare outcomes (fewer wounds, better feather quality, feather cleanliness, and footpad condition) among treatment groups (Table 4).

There were some age-related differences in welfare measures that were unique to some treatment groups. Specifically, P turkeys were 19.159 times more likely to have better neck feather cleanliness at 8 wk than at 19 wk (95% CL 1.093 – 335.8; P = 0.043), and 7.128 times more likely to have better back feather cleanliness at 8 wk than at 19 wk (95% CL 1.207 – 42.088; P = 0.03). Rump feather cleanliness was better at 8, 12 and 19 wk compared to 16 wk for P turkeys (8 vs. 16 wk: 79.556, 4.597 – 1376.7; P = 0.003; 12 vs. 16 wk: 39.815, 2.23 – 710.9; P = 0.012; 16 vs. 19 wk: 0.191, 0.065 – 0.564; P = 0.003. In the B group, tail feather cleanliness was 4.709 times more likely to be better at 16 wk than at 19 wk (95% CL 2.167 – 10.232; P < 0.001). In the T group, turkeys were 20.912 times more likely to have fewer head wounds at 8 wk than at 16 wk (95% CL 1.11 – 394; P = 0.042).

Age significantly affected the majority of turkey welfare measures:

1) wounds (head: Wald χ^2 = 8.529, P = 0.036; neck: Wald χ^2 = 13.486, P = 0.004; tail: Wald χ^2 = 9.791, P = 0.02),

2) feather quality (neck: Wald $\chi^2 = 34.725$, $P < 0.001$; back: Wald $\chi^2 = 8.409$, $P = 0.038$; rump: Wald $\chi^2 = 11.881$, $P = 0.008$; coverts: Wald $\chi^2 = 10.811$, $P = 0.013$; wings: Wald $\chi^2 = 28.788$, $P < 0.001$),
3) feather cleanliness (neck: Wald $\chi^2 = 15.411$, $P = 0.002$; back: Wald $\chi^2 = 20.19$, $P < 0.001$; rump: Wald $\chi^2 = 13.967$, $P = 0.003$; breast: Wald $\chi^2 = 186.261$, $P < 0.001$; belly: Wald $\chi^2 = 214.396$, $P < 0.001$; wings: Wald $\chi^2 = 43.474$, $P < 0.001$; tail: Wald $\chi^2 = 6.184$, $P = 0.013$), and
4) footpad condition (Wald $\chi^2 = 62.379$, $P < 0.001$).

Table 2.4. Probability and odds ratio estimates for the overall influence of treatment on welfare measures

Group	Odds ratio estimate (95% CL) for having a lower score[1]										
	Feather quality[2]			Feather cleanliness							Other
	Neck	Coverts	Wings	Neck	Back	Rump	Breast	Belly	Wings3	Tail	Footpad
S vs. PS	0.826 (0.398 – 1.715)	1.387 (0.344 – 5.601)	**3.734 (1.473 – 9.463) **[4]**	0.351 (0.016 – 7.901)	3.336 (0.541 – 20.588)	3.287 (0.142 – 76.06)	**2.943 (1.587 – 5.458) *****	**2.755 (1.347 – 5.636) ****	0.923 (0.515 – 1.654)	**0.269 (0.122 – 0.592) ****	1.474 (0.604 – 3.601)
S vs. B	1.116 (0.564 – 2.208)	**8.273 (2.678 – 25.56) *****	**5.804 (2.014 – 16.728) ****	3.357 (0.545 – 20.687)	2.523 (0.385 – 16.555)	14.481 (0.858 – 244.4)	**3.374 (1.821 – 6.25) *****	**2.77 (1.363 – 5.63) ****	1.435 (0.805 – 2.559)	0.592 (0.254 – 1.381)	2.297 (0.995 – 5.302)
S vs. C	0.489 (0.216 – 1.107)	**3.836 (1.167 – 12.61) ***	1.687 (0.799 – 3.563)	0.325 (0.014 – 7.302)	1.001 (0.109 – 9.193)	9.534 (0.541 – 168.1)	**3.41 (1.848 – 6.291) *****	**2.493 (1.237 – 5.025) ***	**2.056 (1.149 – 3.68) ***	1.106 (0.435 – 2.809)	1.638 (0.688 – 3.901)
S vs. P	0.6208 (0.286 – 1.347)	**4.277 (1.313 – 13.935) ***	**2.546 (1.117 – 5.803) ***	**6.815 (1.228 – 37.818) ***	**9.179 (1.71 – 49.272) ****	**47.575 (3.007 – 752.7) ****	1.298 (0.706 – 2.387)	0.709 (0.346 – 1.452)	**2.094 (1.162 – 3.773) ***	2.325 (0.738 – 7.327)	1.581 (0.656 – 3.811)
S vs. T	**0.279 (0.105 – 0.742) ***	0.735 (0.146 – 3.696)	1.074 (0.54 – 2.139)	4.797 (0.834 – 27.607)	3.187 (0.517 – 19.651)	9.734 (0.552 – 171.6)	1.785 (0.975 – 3.269)	1.897 (0.941 – 3.821)	1.118 (0.629 – 1.99)	0.607 (0.26 – 1.417)	**2.879 (1.274 – 6.505) ***

Table 2.4. continued

Group	Odds ratio estimate (95% CL) for having a lower score[1]										
	Feather quality[2]			Feather cleanliness							Other
	Neck	Coverts	Wings	Neck	Back	Rump	Breast	Belly	Wings[3]	Tail	Footpad
PS vs. B	1.35 (0.654 – 2.787)	**5.964 (2.153 – 16.523) *****	1.554 (0.452 – 5.344)	9.567 (0.554 – 165.1)	0.756 (0.188 – 3.041)	4.405 (0.758 – 25.608)	1.146 (0.618 – 2.126)	1.006 (0.493 – 2.051)	1.555 (0.861 – 2.809)	**2.201 (1.078 – 4.49) ***	1.558 (0.714 – 3.4)
PS vs. C	0.592 (0.253 – 1.388)	2.766 (0.933 – 8.203)	0.452 (0.169 – 1.208)	0.926 (0.021 – 41.674)	0.3 (0.049 – 1.853)	2.9 (0.466 – 18.07)	1.159 (0.627 – 2.141)	0.905 (0.447 – 1.833)	**2.229 (1.23 – 4.04) ****	**4.113 (1.823 – 9.28) *****	1.111 (0.492 – 2.507)
PS vs. P	0.752 (0.334 – 1.692)	**3.084 (1.05 – 9.057) ***	0.682 (0.241 – 1.932)	**19.4249 (1.2020 – 313.9) ***	2.751 (0.911 – 8.305)	**14.472 (2.767 – 75.706) ****	**0.441 (0.237 – 0.82) ****	**0.257 (0.123 – 0.539) *****	**2.27 (1.244 – 4.141) ****	**8.648 (3.015 – 24.805) *****	1.072 (0.469 – 2.451)
PS vs. T	**0.338 (0.123 – 0.925) ***	0.53 (0.113 – 2.474)	**0.288 (0.112 – 0.737) ****	13.674 (0.827 – 226)	0.955 (0.259 – 3.528)	2.961 (0.475 – 18.454)	0.607 (0.329 – 1.12)	0.688 (0.339 – 1.399)	1.212 (0.673 – 2.183)	**2.259 (1.107 – 4.61) ***	1.953 (0.916 – 4.164)
B vs. C	**0.439 (0.195 – 0.987) ***	**0.464 (0.228 – 0.944) ***	**0.291 (0.096 – 0.878) ***	0.097 (0.006 – 1.667)	0.397 (0.06 – 2.606)	0.658 (0.196 – 2.208)	1.011 (0.549 – 1.861)	0.9 (0.447 – 1.81)	1.433 (0.796 – 2.581)	1.869 (0.783 – 4.464)	0.713 (0.337 – 1.512)
B vs. P	0.557 (0.258 – 1.201)	0.517 (0.258 – 1.037)	0.439 (0.138 – 1.396)	2.03 (0.636 – 6.48)	**3.638 (1.092 – 12.115) ***	**3.285 (1.304 – 8.278) ***	**0.385 (0.207 – 0.714) ****	**0.256 (0.123 – 0.532) *****	1.46 (0.805 – 2.646)	**3.93 (1.311 – 11.785) ***	0.688 (0.32 – 1.479)
B vs. T	**0.25 (0.095 – 0.662) ****	**0.089 (0.024 – 0.327) *****	**0.185 (0.064 – 0.538) ****	1.429 (0.424 – 4.813)	1.263 (0.314 – 5.074)	0.672 (0.2 – 2.255)	**0.529 (0.287 – 0.975) ***	0.685 (0.339 – 1.381)	0.779 (0.435 – 1.397)	1.027 (0.472 – 2.235)	1.253 (0.629 – 2.496)

Table 2.4. continued

Group	Odds ratio estimate (95% CL) for having a lower score[1]										
	Feather quality[2]			Feather cleanliness							Other
	Neck	Coverts	Wings	Neck	Back	Rump	Breast	Belly	Wings[3]	Tail	Footpad
C vs. P	1.269 (0.521 – 3.09)	1.115 (0.505 – 2.463)	1.51 (0.624 – 3.653)	**20.989 (1.301 – 338.8) ***	**9.17 (1.706 – 49.296) ****	**4.99 (1.746 – 14.266) ****	**0.381 (0.206 – 0.704) ****	**0.285 (0.138 – 0.587) *****	1.019 (0.56 – 1.851)	2.103 (0.656 – 6.739)	0.965 (0.434 – 2.147)
C vs. T	0.571 (0.196 – 1.666)	**0.192 (0.049 – 0.744) ***	0.637 (0.298 – 1.362)	14.775 (0.895 – 243.8)	3.184 (0.516 – 19.653)	1.021 (0.276 – 3.78)	**0.524 (0.285 – 0.961) ***	0.761 (0.38 – 1.524)	**0.544 (0.303 – 0.978) ***	0.549 (0.23 – 1.311)	1.757 (0.849 – 3.636)
P vs. T	**0.45 (0.159 – 1.271)**	**0.172 (0.045 – 0.663) ***	**0.422 (0.183 – 0.973) ***	**0.704 (0.246 – 2.011)**	**0.347 (0.115 – 1.047)**	**0.205 (0.072 – 0.585) ****	**1.375 (0.749 – 2.527)**	**2.675 (1.3 – 5.504) ****	**0.534 (0.295 – 0.966) ***	**0.261 (0.087 – 0.783) ***	**1.821 (0.867 – 3.822)**

S = straw bale group, B = pecking block group, T = tunnel group, P = platform group, PS = platform + straw bale group, C = control group

[1]Back wounds were assessed; however, all birds had a score of 0. No difference was found for head, neck or tail wounds.

[2]No difference was found on feather quality on back, rump or tail.

[3]Feather cleanliness on wings and tail were only assessed for 16 vs. 19 wk.

[4]* P < 0.05, ** P < 0.01, *** P < 0.001

Age-related changes in welfare measures within each treatment group

Within treatment groups, various welfare measures changed with age, and changes in feather quality of the neck and wings, footpad condition and feather cleanliness of the breast, belly and wings were similar for several treatment groups.

Neck feather quality was worse at 19 wk than at earlier time points for turkeys in S and C groups. Turkeys in the S group were more likely to have better feather quality at 8 (odds ratio and 95% CL: 15.730; 2.804 – 88.271; P = 0.002), 12 (25.600; 1.441 – 454.8; P = 0.027) and 16 (8.210; 1.413 – 47.704; P = 0.019) wk than at 19 wk. Neck feather quality was worse at 16 wk than at other time points for turkeys in P and PS groups. Turkeys in the P group were 5.085 times more likely to have better neck feather quality at 8 wk than at 16 wk (95% CL 1.078 – 23.982; P = 0.0400). Similarly, Turkeys in the PS group were 38.638 times more likely to have better neck feather quality at 8 wk (95% CL 2.168 – 688.5; P = 0.013), and 19.706 times more likely at 12 wk (95% CL 1.069 – 363.3; P = 0.045) than at 16 wk.

Wing feather quality improved with age for turkeys in S and T groups. In the S group, turkeys at 8 wk were less likely to have better wing feather quality than at 16 wk (0.036; 95% CL 0.002 – 0.702; P = 0.028), and 19 wk (0.023; 95% CL 0.001 – 0.416; P = 0.011). Similarly, turkeys in the T group were less likely to have better wing feather quality at 8 wk than at 19 wk (0.145; 95% CL 0.035 – 0.61; P = 0.008).

Footpad condition worsened over time for turkeys in all treatment groups except for the S group. Turkeys in the P (26.116; 1.543 – 441.9; P = 0.024), PS (19.947; 1.161 – 342.6; P = 0.039), B (39.573; 2.334 – 670.9; P = 0.011), T (66.165; 3.947 – 1109.3; P = 0.004) and C (34.372; 2.051 – 576.2; P = 0.014) groups were more likely to have better footpad condition at 8 wk than at 19 wk. Similarly, turkeys in the B (20.721; 1.185 – 362.3; P = 0.038), T (34.674; 2.004 – 599.8; P = 0.015), and C (18.351; 1.062 – 317.2; P = 0.045) groups were more likely to have better footpad condition at 12 wk than at 19 wk. In addition, turkeys in the T (10.994; 1.947 – 62.077; P = 0.007) and C (5.829; 1.018 – 33.371; P = 0.048) groups were more likely to have better footpad condition at 16 wk than at 19 wk. Footpad condition was better at 8 than at 16 wk for turkeys in the B group (19.97; 1.052 – 379; P = 0.046).

Results from postmortem assessment of footpad dermatitis were consistent with results collected prior to processing. Turkeys in the S group had the lowest prevalence of footpad dermatitis compared to P (15.463; 3.656 – 65.395; P < 0.001), PS (7.134; 1.814 – 28.063; P =

0.005), B (8.537; 2.148 – 33.938; P = 0.002), T (19.501; 4.443 – 85.585; P < 0.001), and C (34.607; 6.904 – 173.5; P < 0.001) turkeys. PS turkeys were also more likely to have better footpad condition compared to C turkeys (4.851; 1.139 – 20.653; P = 0.033).

Breast feather cleanliness was better at 8 and 12 wk than at 19 wk for turkeys in all treatment groups (Table 5). Turkeys in S, P T and C groups also had cleaner feathers at 16 vs. 19 wk. Breast feather cleanliness was better at 8 versus 16 wk in PS, B, T and C groups. PS, B and C turkeys also had cleaner feathers at 12 versus 16 wk. In addition, P turkeys had better breast cleanliness at 8 versus 12 wk. Similar to breast feather cleanliness, belly feather cleanliness was better at 8, 12 and 16 wk than at 19 wk in all treatment groups. Belly feather cleanliness was also better at 8 and 12 versus 16 wk in PS, B and C groups. Wing feather cleanliness was better at 16 versus 19 wk in S, B, T and C groups. Pairwise comparison results of breast, belly and wing feather cleanliness are presented in Table 5.

Table 2.5. Probability and odds ratio estimates for significant age-related changes in feather cleanliness within each treatment group

5	Age (wk)	Odds ratio estimate (95% CL) of having better condition		
		Breast feather cleanliness	**Belly feather cleanliness**	**Wing feather cleanliness**
S	**8 vs. 19**	205.7 (12.08 – 3501.2) ***	4823.2 (93.718 – 248224) ***	
	12 vs. 19	13.861 (3.994 – 48.104) ***	815.2 (32.034 – 20747.3) ***	
	16 vs. 19	107.5 (6.113 – 1889.2) **	2585.8 (48.365 – 138243) ***	1.557 (1.015 – 2.39) *
P	**8 vs. 12**	20.91 (1.066 – 410.4) *		
	8 vs. 19	303.7 (17.124 – 5385.9) ***	505.6 (126.245 – 9741.6) ***	
	12 vs. 19	14.524 (4.264 – 49.473) ***	44.811 (8.808 – 228) ***	
	16 vs. 19	47.476 (7.786 – 289.5) ***	248.8 (12.266 – 5045.1) ***	
PS	**8 vs. 16**	154.9 (8.758 – 2740.9) ***	122.8 (6.785 – 2224.4) **	
	12 vs. 16	25.449 (4.188 – 154.6) ***	11.709 (2.548 – 53.804) **	
	8 vs. 19	276.5 (16.187 – 4721.2) ***	394.6 (22.338 – 6970.7) ***	
	12 vs. 19	45.407 (7.911 – 260.6) ***	37.611 (8.599 – 164.5) ***	
	16 vs. 19		3.212 (1.258 – 8.205) *	
B	**8 vs. 16**	242.6 (13.607 – 4324.2) ***	139.6 (7.301 – 2669.1) **	
	12 vs. 16	128.8 (6.983 – 2376.6) **	72.762 (3.627 – 1459.6) **	
	8 vs. 19	307 (17.874 – 5272.3) ***	1896.6 (84.748 – 42443.6) ***	
	12 vs. 19	163 (9.168 – 2899) ***	988.6 (42.244 – 23133.3) ***	
	16 vs. 19		13.586 (3.355 – 55.017) ***	2.101 (1.339 – 3.296) **
T	**8 vs. 16**	21.668 (1.083 – 433.7) *		
	8 vs. 19	1029.8 (49.123 – 21588.3) ***	1570 (71.55 – 34448.3) ***	
	12 vs. 19	537.9 (24.544 – 11787.7) ***	837.9 (36.679 – 19141.2) ***	
	16 vs. 19	47.527 (10.003 – 225.8) ***	796.3 (34.957 – 18140.1) ***	3.555 (1.997 – 6.328) ***
C	**8 vs. 16**	122.2 (6.971 – 2143.3) **	129.3 (6.869 – 2433.6) **	
	12 vs. 16	65.275 (3.606 – 1181.6) **	69.224 (3.519 – 1361.6) **	
	8 vs. 19	502 (29.024 – 8682.7) ***	986.9 (49.903 – 19517.8) ***	
	12 vs. 19	268.1 (15.012 – 4787.1) ***	528.4 (25.592 – 10909.2) ***	
	16 vs. 19	4.107 (1.667 – 10.12) **	7.633 (2.457 – 23.71) **	2.184 (1.401 – 3.404) ***

S = straw bale group, B = pecking block group, T = tunnel group, P = platform group, PS = platform + straw bale group, C = control group

*** P < 0.05, ** P < 0.01, *** P < 0.001**

2.5.2 Gait assessment and foot and toe abnormalities

The percentage of turkeys/treatment group with each gait score is presented in Table 6. Age significantly affected gait scores of the birds (Wald $\chi^2 = 209.806$, $P < 0.001$) while treatment had no overall effect on gait scores. Gait worsened with increasing age in all treatment groups. Gait was worst in the S (Wald $\chi^2 = 36.455$, $P < 0.001$), P (Wald $\chi^2 = 40.357$, $P < 0.001$), PS (Wald $\chi^2 = 47.698$, $P < 0.001$) and B (Wald $\chi^2 = 39.091$, $P < 0.001$) groups at 19 wk compared to 8, 12 and 16 wk, while gait in T (Wald $\chi^2 = 38.166$, $P < 0.001$) and C (Wald $\chi^2 = 38.129$, $P < 0.001$) groups worsened starting at 16 wk (Table 7).

Few abnormalities of the feet and toes were observed across all ages. In the S group, three birds had joint swelling (1 at 16 wk and 2 at 19 wk). In the PS group, one bird had shaky legs at 16 wk, three birds had joint swelling, one bird had a valgus deformity, one bird had a varus deformity, and three birds had curl toes at 19 wk. In the B group, three birds had curl toes (1 at 16 wk and 2 at 19 wk), one bird had joint swelling, and three birds had a valgus deformity at 19 wk. In the C group, one bird had shaky legs at 16 wk, two birds each had a swollen toe at 19 wk, and three birds had curl toes (2 at 16 wk and 1 at 19 wk). In the P group, six birds had joint swelling (3 at 16 wk and 3 at 19 wk), two birds had shaky legs, and one bird had a valgus deformity at 19 wk. In the T group, two birds had shaky legs at 16 wk, four birds had joint swelling, and three birds had curl toes at 19 wk.

Table 2.6. Percentage of turkeys in each treatment group with each gait score at 8, 12, 16, and 19 wk

Treatment	Age (wk)	Gait score					
		0	**1**	**2**	**3**	**4**	**5**
S	**8**	100	0	0	0	0	0
	12	100	0	0	0	0	0
	16	95.59	4.41	0	0	0	0
	19	56.72	41.79	1.49	0	0	0
PS	**8**	98.46	0	0	1.54	0	0
	12	100	0	0	0	0	0
	16	90.48	9.52	0	0	0	0
	19	44.44	47.62	7.94	0	0	0
B	**8**	100	0	0	0	0	0
	12	100	0	0	0	0	0
	16	93.85	6.15	0	0	0	0
	19	51.56	37.5	10.94	0	0	0
C	**8**	98.53	0	0	0	1.47	0
	12	100	0	0	0	0	0
	16	88.06	11.94	0	0	0	0
	19	53.03	42.42	4.55	0	0	0
P	**8**	100	0	0	0	0	0
	12	100	0	0	0	0	0
	16	92.31	7.69	0	0	0	0
	19	49.23	44.62	6.15	0	0	0
T	**8**	100	0	0	0	0	0
	12	98.48	0	1.52	0	0	0
	16	87.88	10.61	0	0	1.52	0
	19	52.31	41.54	6.15	0	0	0

S = straw bale group, B = pecking block group, T = tunnel group, P = platform group, PS = platform + straw bale group, C = control group

Table 2.7. Probability and odds ratio estimates for age-related changes in gait score within each treatment group

Treatment	Odds ratio estimate (95% CL) of having better condition[1]					
	8 vs. 12 wk	**8 vs. 16 wk**	**8 vs. 19 wk**	**12 vs. 16 wk**	**12 vs. 19 wk**	**16 vs. 19 wk**
S	1.009 (0.02 – 51.157)	7.421 (0.378 – 145.8)	**110.1 (6.5538 – 1850.9) ****	7.356 (0.374 – 144.6)	**109.2 (6.4890 – 1836.3) ****	**14.8407 (4.5124 – 48.8092) *****
PS	0.334 (0.013 – 8.28)	4.845 (0.794 – 29.547)	**52.3906 (9.6648 – 284.0) *****	14.517 (0.805 – 261.7)	**157 (9.3622 – 2632.5) *****	**10.8145 (4.1739 – 28.0201) *****
B	1.019 (0.02 – 51.636)	9.901 (0.525 – 186.6)	**129.9 (7.7299 – 2183.3) *****	9.713 (0.515 – 183.1)	**127.4 (7.5832 – 2142) *****	**13.1214 (4.4341 – 38.8291) *****
P	1.03 (0.02 – 51.979)	12.434 (0.68 – 227.4)	**138.7 (8.3123 – 2315.8) *****	12.071 (0.659 – 221)	**134.7 (8.0616 – 2250.2) *****	**11.1582 (4.1050 – 30.3306) *****
T	3.084 (0.124 – 76.699)	**19.5311 (1.1080 – 344.3) ***	**121.7 (7.2538 – 2041.6) *****	**6.333 (1.0777 – 37.2142) ***	**39.4592 (7.2836 – 213.8) *****	**6.2307 (2.6055 – 14.9) *****
C	0.329 (0.013 – 8.161)	**6.3998 (1.0913 – 37.5297) ***	**39.2273 (7.2644 – 211.8) *****	**19.4726 (1.1062 – 342.8) ***	**119.4 (7.1287 – 1998.4) *****	**6.1294 (2.5746 – 14.5928) *****

S = straw bale group, PS = platform + straw bale group, B = pecking block group, P = platform group, T = tunnel group, C = control group

[1]* P < 0.05, ** P < 0.01, *** P < 0.001

2.6 Discussion

To the best of our knowledge, this is the first study to examine the effects of different types of environmental enrichment on gait and age-related changes in turkey welfare measures and walking ability. Our results indicate that age had an overall effect on the majority of welfare measures, and different enrichments had an overall effect mostly on feather quality and feather cleanliness. Compared to earlier ages, neck feather quality was worst at 19 wk in the straw bale and control groups, while worst at 16 wk then improved at 19 wk in the platform and platform + straw bale groups. Wing feather quality improved with age in the straw bale and tunnel groups. Footpad condition worsened over time for turkeys in all treatment groups except for the straw bale group. Breast, belly and wing feather cleanliness worsened with age in all treatment groups. Gait was worst at 19 wk compared to all other time points in the straw bale, platform, straw bale +

platform and pecking block groups, whereas gait started worsening for birds in the tunnel and control groups at 16 wk. Feet and toe abnormalities were observed infrequently.

2.6.1 Influence of EE on welfare measures

Feather condition

Neck feather damage can often be caused by aggressive pecking, which is specifically aimed at the head and neck areas (Dalton et al., 2018) and can also be caused by feather pecking (Bilčík and Keeling, 2000). A previous study reported that injurious pecking on the head and neck areas often originated from fights in small turkey flocks as turkeys attempt to establish their social hierarchy, which begins around 8 wk (Bartels et al., 2020). Previous research demonstrated that the provision of an elevated platform structure ('turkey tree') as enrichment was beneficial in reducing feather pecking and fighting and resulted in improved feather quality (Lindenwald et al., 2021). Our results agree with those of Lindenwald et al. (2021); turkeys provided with platforms or platforms and straw bales had improved feather condition compared to turkeys in other treatment groups. The platforms in this study provided turkeys with additional space and areas to potentially avoid or escape injurious pecking and aggression. Although straw bales can also serve as elevated structures, the bales provided limited space for turkeys to avoid aggressive conspecifics compared to the elevated platform, because turkeys provided with platforms had access to the top, as well as to areas underneath the platform and ramps. However, use of the space underneath the platform and ramps was not systematically assessed, so the extent to which turkeys used this space is unknown.

Our observations of better wing feather quality with age for turkeys in the straw bale group were consistent with findings of Martrenchar et al. (2001) who reported reduced wing damage in birds provided with straw bales. Straw bales are one of the primary enrichments recommended for turkeys, as they can satisfy turkeys' pecking and foraging needs (G.A.P., 2020). Turkeys provided with a tunnel as enrichment had better wing feather quality at 19 wk. The tunnel was designed to give turkeys a secluded rest area as well as an opportunity to hide from and avoid their conspecifics, as tunnel walls can serve similar functions to visual barriers (e.g. free-standing wooden boards). Results from the tunnel group were consistent with those of Sherwin et al. (1999b), who reported that visual barriers can help reduce wing and tail pecking injuries in turkeys. Visual barriers are

listed as a secondary enrichment to provide turkeys with a hiding structure in the G.A.P. standards (G.A.P., 2020). Anecdotally, we also observed turkeys resting on top of the tunnel at young ages, indicating that the tunnel may also serve as an elevated space, at least when turkeys are young. It is important to note, however, that tunnels had to be reinforced with a second corrugated plastic sheet as turkeys grew heavier because the tunnels became flattened as the turkeys continued to attempt to rest on them.

When examining feather condition, it is important to consider when turkey feathers molt, because feather development and molting may also influence turkey feather condition, and hence, how feather condition is scored in welfare assessments. Juvenile turkeys usually start to molt their primary wing feathers at 5 wk, and molting continues approximately every week until 10 wk when the molting interval slows to every 2 to 3 weeks until 20 wk (later ages not observed) (Leishman et al., 2020). Turkeys begin to molt their body plumage at 7 wk, starting across the breast, then continuing to the back and belly, and lastly the neck. At 14 wk, new feathers often appear on the neck and the post juvenal feathers are mostly fully developed on all body regions except the head (Leopold, 1943). In our study, neck feather condition was observed to be worst after 16 wk, which is after neck feather molting would have been completed. Wing feather condition was observed to worsen from 8 wk until the end of the study at 19 wk, which coincided with the molting of wing feathers. However, feather condition scored as 1 or 2 in this study was due to broken feathers (the ends of feathers were damaged or broken), likely caused by feather pecking, and not molting (bald patches with newly emerging feathers).

Footpad condition

The worst footpad condition was observed at 19 wk in the platform, platform + straw bale, tunnel and control groups while footpad condition for turkeys in the pecking block group worsened from 16 wk. Footpad condition did not worsen with age for turkeys provided with a straw bale. Postmortem assessment of footpad dermatitis confirmed that the straw bale group had the best footpad condition and the platform + straw bale had better footpad condition than the control group. Footpad condition is affected by multiple factors including litter condition, environmental conditions (e.g. temperature and humidity), drinker design, stocking density, body weight, group size and diet etc. (Erasmus, 2018). The most influential factor causing footpad dermatitis is high litter moisture; the exposure of turkeys to wet litter without feces and urine for 8 hr/day was

sufficient to cause bad footpad lesions (Youssef et al., 2011). The bell drinker used in this study was observed to be bumped by turkeys and water spills happened on several occasions. Attempts were made to add fresh, dry shavings when spills occurred, but wet litter because of water spills likely resulted in the worsening footpad condition observed in this study. The worse footpad condition observed at later ages may also be related to turkeys' larger body size and higher body weight, which result in both increased area of contact surface and higher contact pressure of footpads with the litter (Shepherd and Fairchild, 2010). Straw bales may have been beneficial in reducing turkeys' contact with wet litter because straw is not as absorptive as wood shavings. Loose straw pulled out from the straw bales may have served as a barrier between turkeys' feet and the wet litter so that worse footpad condition was not observed in the straw bale group. Footpad condition of turkeys in the platform + straw bale group was slightly worse than turkeys provided only with a bale, as the platform occupied a large amount of the space in the pen and may have limited the floor space over which loose straw could be scattered. However, the platform + straw bale group still had a lower prevalence of footpad dermatitis compared to the control group. Previous studies have not examined the influence of environmental enrichment on turkeys' footpad condition and further work is needed to examine the interactive effects among litter management, litter condition, environmental enrichment and footpad condition.

2.6.2 Influence of EE on gait score

Previous studies have linked rapid weight gain and exacerbated growth of the breast muscle with gait impairments and reduced walking ability in turkeys (Erasmus, 2018; Hester, 1994; Shepherd and Fairchild, 2010). However, limited research to date has examined the influence of environmental enrichment on turkey walking ability. One study, Sherwin et al. (1999a), reported potentially improved skeletal health in turkeys provided with various types of enrichment (wooden board with rope and screws attached, reflective sheeting sandwiched between clear acrylic sheets, cabbages, and supplemental spotlights that turned on and off). Other studies with broiler chickens have suggested a link between environmental enrichment, activity level, and walking ability. Better walking ability (better gait) for broilers with access to platforms was reported by Kaukonen et al. (2017), and they suggested that birds benefited from the locomotor activity required to use the platform. Similarly, Bailie et al. (2013) reported that lameness was worse for broiler chickens that had not been provided with a straw bale compared to broilers that had access to a straw bale,

and Bizeray et al. (2002b) suggested that providing wood barriers increased broilers' activity levels. While we found no overall effect of enrichment type on gait score of turkeys in this study, the finding that gait worsened at 16 wk for turkeys in the control and tunnel groups, compared to gait worsening at 19 wk for turkeys provided with a straw bale, platform, straw bale and platform or pecking block suggests that there may be some beneficial effects of enrichment on gait that warrants further investigation. Both pecking and foraging enrichment (straw bale or pecking block) and elevated structures (straw bale or platform) can provide opportunities for turkeys to perform more activities and more locomotion compared to control conditions. However, further work is needed to clearly establish whether these enrichments or the amount or type of space available in a pen influence gait and activity level.

2.6.3 Age-related changes in welfare measures and gait

Feather condition

In previous studies, age was reported to affect turkey feather condition. For example, Duggan et al. (2014) reported that the average feather condition of the neck, back, wings, and tail improved from 9 to 15 wk (no observations at later ages) in turkeys housed in entirely enclosed commercial barns, whereas feather condition was worst at 15 wk in turkeys housed in curtain-sided commercial barns. Others have reported that feather pecking became more prevalent with age (Marchewka et al., 2013) and the incidence of feather pulls increased with age from 3 to 9 wk (Busayi et al., 2006). In the present study, wing feather quality improved with age in straw bale and tunnel groups, and neck feather quality was better from 16 to 19 wk in platform and platform + straw bale groups. Our findings differ from results reported by Duggan et al., (2014) who collected data from commercial farms. However, group size, stocking density and environmental conditions were different between the two studies and a direct comparison of results is not possible (group size: 16 – 18 birds per pen in this study vs. around 4800 birds per barn in Duggan et al. (2014); stocking density: 2.15 to 2.42 birds/m^2 in this study vs. 2.56 to 2.78 birds/m^2 in Duggan et al., (2014)). Further work is needed to determine the influence of environmental enrichment on feather condition. In particular, it will be important to examine whether feather pecking behavior differs among turkeys provided with different types of enrichment because feather condition scoring is an indirect measure of feather pecking behavior.

Footpad condition

Consistent with results of Da Costa et al. (2014) and Krautwald-Junghanns et al. (2013), our results indicated that footpad dermatitis worsened with age. Worsening footpad condition was observed as early as 16 wk for turkeys with pecking blocks, which was consistent with results reported by Krautwald-Junghanns et al., (2013). However, turkeys in the straw bale group showed no difference in footpad condition across all ages, and turkeys in the remaining treatment groups did not show the worst footpad condition until 19 wk.

Gait

Several studies have documented a decrease in walking ability (worsening gait) as turkeys get older and heavier (e.g. Da Costa et al., 2014; Dalton et al., 2016; Stevenson et al., 2019; Taskin et al., 2018), and our results are consistent with these reports as we observed a decline in gait with age in all treatment groups. Gait scores worsened in T and C turkeys from 16 wk onward and in turkeys in all other treatment groups at 19 wk; however, gait was not assessed between 16 and 19 wk and further research is needed to determine how gait worsens between 12 and 16 and between 16 and 19 wk. These results are similar to those of Da Costa et al. (2014) who reported that gait was significantly worse in turkeys at 16-20 wk than at 13-15 wk, whereas Dalton et al. (2016) documented a decline in gait from 13 wk onward. Stevenson et al. (2019) also reported poorer gait when tom turkeys aged, as turkeys spent more time on both feet and took fewer steps per minute from 16 wk onward. Turkey walking ability can be affected by multiple environmental and management factors, such as environmental temperature and humidity level (Hester, 1994), and the specific genetic strain of turkey used. Further research will be beneficial in examining how various environmental and genetic factors influence age-related changes in turkey walking ability.

2.7 Study limitations

As our study was conducted on a research farm, there are several limitations that need to be considered when interpreting the results. The group size and stocking density of the birds in each pen do not represent typical conditions on commercial turkey farms. Commercial turkey management guidelines for the turkeys used in this study suggest a stocking density of 2.5-3 birds/m^2 (Aviagen Turkeys, 2015). However, the stocking density of the birds in this study (2.15

to 2.42 birds/m^2) was lower than the commercial stocking densities to ensure enough space for the various enrichments. High stocking density and large group size are influential factors in promoting injurious pecking in turkeys, as well as other injuries such as broken wings due to hitting the walls, equipment or other birds because of insufficient space (Krautwald-Junghanns and Sirovnik, 2022). Other limiting factors in the present study were the size of the pen and the fixed locations of the feeders and the drinkers, which affected the placement of platforms (i.e. platforms could only be placed in one corner of the pen), which potentially limited turkey access and movement (two ramps were attached to platforms to ensure access). In addition, this study was conducted during the spring and summer seasons, which may not reflect possible seasonal factors that could influence injurious pecking behavior or walking ability. Future research will be valuable in examining variations among flocks and seasonal factors.

2.8 Conclusion

Age affected the majority of welfare measures and gait in tom turkeys. Different types of environmental enrichment influenced feather quality and feather cleanliness but had little overall effect on gait under the conditions of this study. Providing tom turkeys with a straw bale and tunnel as environmental enrichment can help improve wing feather quality with age and providing straw bales may reduce the development of footpad dermatitis under suboptimal litter conditions. Providing enrichments that can help increase turkey activity and locomotion, including enrichment that can satisfy turkeys' pecking and foraging needs (straw bale or pecking block) and elevated structures (bale or platform), may be beneficial for turkey walking ability, but further research is needed to investigate the links among activity level, space, enrichment, and walking ability.

CHAPTER 3. EFFECTS OF DIFFERENT ENVIRONMENTAL ENRICHMENTS ON TOM TURKEY BEHAVIOR

3.1 Abstract

Research with chickens has demonstrated the benefits of environmental enrichment in improving animal welfare and mitigating injurious pecking behavior, but the influence of different forms of environmental enrichment on the behavior of modern commercial turkeys is unknown. This study investigated the effects of five different types of environmental enrichment on turkey behavior (enrichment usage, aggressive pecking, feather pecking, preening, and environmental pecking). Tom turkeys (n = 420) were randomly assigned to: straw bale, platform, platform + straw bale, pecking block, tunnel or control (no enrichment) groups. Behavior of turkeys was video recorded at 8, 12 and 16 wk and analyzed using scan sampling. The proportions of turkeys performing target behaviors was determined every 15 min (07:00 h - 22:00 h). Scan sampling data were analyzed using PROC GLIMMIX. The average proportion of turkeys using environmental enrichments declined with age (8 vs 12 wk: $P = 0.035$; 8 vs 16 wk: $P < 0.001$). Turkeys provided with a platform + straw bale ($P < 0.001$) had the highest levels of enrichment usage, followed by the platform group ($P < 0.001$). Preening and severe feather pecking behavior did not change with age and were unaffected by the type of enrichment provided. Aggressive pecking and gentle feather pecking were not influenced by the type of enrichment provided. Higher average proportions of turkeys were observed performing environmental pecking when no enrichment was provided than in the platform + straw bale group ($P = 0.001$). Turkeys' usage of enrichments mainly included resting on top, locomotion, pecking and remaining under the enrichment when they had access to platforms; resting on top, locomotion and pecking when they had access to straw bales or pecking blocks; and remaining in the tunnel and pecking when they had access to a tunnel. In conclusion, turkeys provided with multi-functional enrichments, especially a combination of different enrichment objects (e.g., platform + straw bale) had the highest enrichment usage. Turkeys gradually lost interest in interacting with enrichments over time, which may be associated with habituation, destruction of some enrichment objects (e.g. straw bale and pecking block) and fecal contami9nation on the surface of enrichments.

3.2 Introduction

Injurious pecking is one of the major behavioral and welfare issues of commercial turkey production. Aggressive pecking and feather pecking are both different categories of injurious pecking of turkeys. Aggressive pecking, which is usually directed at the head, neck and snood of turkeys (Buchwalder and Huber-Eicher, 2003; reviewed in Erasmus, 2018), is mainly reported in turkey toms. Aggressive pecking can cause problematic issues including injuries to the head, skin and underlying tissue, requiring culling by the producer and even resulting in death in extreme cases (Bartels et al., 2020; Buchwalder and Huber-Eicher, 2003; Buchwalder and Huber-Eicher, 2004; Dalton et al., 2013; reviewed in Erasmus, 2018). While gentle feather pecking usually causes little or no damage to the birds, severe feather pecking is a forceful pecking behavior that may cause feather and/or skin damage (Dalton et al., 2013; Rodenburg et al., 2013; Savory, 1995; reviewed in Erasmus, 2018). These abnormal behaviors result in reduced welfare and suffering and economic concerns because of increased carcass damage, culling rate and mortality (Bartels et al., 2020).

In current practice, infrared beak treatment and reduced light intensity are common approaches to deal with injurious pecking issues in turkey production. However, both methods can lead to welfare concerns in turkeys. Although turkeys receiving infrared beak treatment showed no evidence of pain or stress based on recent studies (e.g. Struthers et al., 2022), inconsistent effects on reducing injurious pecking related damage were found (Struthers et al., 2022). In addition, beak treatment in turkeys will be banned in Europe in the near future with the increased public discussion and welfare concerns on non-curative operations in animals (Bartels et al., 2020). The management practice of reducing light intensity in turkey barns reportedly does not reduce injurious pecking and related mortality rates (Bartels et al., 2020; Marchewka et al., 2019). In addition, low light intensity can negatively affect eye development and cause impaired vision and may lead to reduced activity levels in turkeys (Nickla et al., 2001; Nicol et al., 2013; reviewed in Erasmus, 2018).

Environmental enrichment, which is the modification to the environment of captive animals to improve their biological functioning (Newberry, 1995), is used as part of animal welfare certification programs (e.g. Global Animal Partnership (G.A.P., 2020), American Humane Certified™ (American Humane, 2020), Certified Humane® (HFAC, 2014), and Farm Animal Care Training and Auditing (FACTA, 2016)) to promote natural behavior of turkeys because

research (e.g. Martrenchar et al. (2001)) has demonstrated that environmental enrichment can help reduce injurious pecking behavior in poultry. Despite the recommended use of enrichment, there is limited information available about environmental enrichments for turkeys, and in particular, how turkeys use different types of enrichment. This information can be of particular importance to turkey producers and animal welfare certification programs as they determine which environmental enrichments to implement on commercial turkey farms.

To investigate the implementation of environmental enrichment in turkeys, the present study provided turkeys with multiple types of occupational enrichments that encourage exercise (platforms and straw bales) and physical enrichments that either altered the space of the environment (platforms and tunnels) or added complexity and stimuli such as objects or substrates for pecking and foraging (pecking blocks and straw bales). Our specific objectives included: (1) the effects of different types of occupational and physical enrichments on turkey injurious pecking behavior and enrichment usage; and (2) specific behaviors turkeys perform when using different enrichment objects and the relative location of the turkeys to the enrichment objects.

3.3 Materials and Methods

3.3.1 Animals and housing

All procedures used in this study were approved by the Institutional Animal Care and Use Committee at Purdue University (PACUC 1904001883). A total of 420 beak-trimmed tom turkeys (Nicolas Select, Aviagen Turkeys, Lewisburg, West Virginia, USA) were housed in 24 littered (wood shavings) pens (measuring 3.05 m by 2.44 m) located in two rooms within the same barn in groups of 16 to 18 birds per pen (stocking density 2.15 to 2.42 birds/m^2) at the Purdue Animal Sciences Research and Education Center until 19 wk when they were processed. A hanging feeder and two bell drinkers were supplied in each pen. Standard commercial feed and water were provided ad libitum. Lighting and temperature were maintained according to standard industry practice (Aviagen Turkeys, 2015). Details on management procedures can be found in Chapter 2.

3.3.2 Environmental enrichment

Turkeys were randomly assigned to six treatment groups with 4 pens per treatment group, including five enrichment groups (straw bale, platform, platform + straw bale, pecking block and

tunnel) and a control group. Environmental enrichments were provided starting at 4 wk. One straw bale (1.02 m length × 0.51 m width × 0.30 m height) was provided in the pen of the straw bale group (S) and straw bales were replaced as necessary, when bales collapsed and birds could no longer jump on the bales, which was similar to Baxter et al. (2018a). One wooden platform with two ramps (overall size: 2.04 m length × 1.65 m width × 0.61 m height) was provided in the pen of the platform group (P). One wooden platform with two ramps (as described above) and one straw bale were provided in the pen of the platform + straw bale group (PS). One rectangular pecking block (0.23 m length × 0.23 m width × 0.18 m height) (provided by Cargill Turkeys) was provided in the pen of the pecking block group (B) and new pecking blocks were placed in the pens as necessary when pecking blocks were destroyed. One tunnel (0.61 m length x 0.61 m width x 0.58 m height) was provided in the pen of the tunnel group (T). Turkeys in the Control group (C) were not provided with any enrichment. Details on enrichment designs and maintenance can be found in Chapter 2.

3.3.3 Behavioral observations

Video recording

Turkey behavior was recorded for two continuous days at 8 wk, 12 wk, and 16 wk with overhead cameras two days after welfare and gait assessments were conducted. Welfare and gait assessments were done at 8, 12, 16 and 19 wk as described in Chapter 2. One video camera (Amcrest motorized varifocal 2MP outdoor dome camera Model: AF-2MVD-VARIB, Amcrest Industries LLC, Houston, TX) was used in each pen to record between 07:00 h and 22:00 h. The video settings used were 960p video resolution. Cameras were positioned at a height of 2.4 m from the floor to record approximately 5.57 m^2 of floor area (75 % of the pen), focusing on the enrichment, and were connected to a DVR (Amcrest 16 channel video security recorder Model: AMDV108116-H5, Amcrest Industries LLC, Houston, TX). Due to pen size and camera hardware limitations, the camera view could not cover the entire floor area, but the camera view encompassed the enrichment so that turkey behavior related to the enrichment objects could be examined.

Scan sampling

Four trained observers (inter-rater reliability using Pearson's correlation coefficient was 0.95) used scan sampling to observe behaviors of the group of turkeys within each pen. Videos were sampled every 15 min from 07:00 h to 22:00 h. The sampling interval was determined based on prior testing of video observations, initially using 5 min intervals from 07:00 h to 22:00 h, and then extending to 15-min intervals. The 15-minute interval was selected because most information could still be captured while ensuring the efficiency, and reducing labor requirements, of conducting video observations. The total number of visible turkeys was counted at each 15-min time point. The videos were observed 5 s before and after each 15-min time point to verify the behavior of interest. The number of turkeys performing each type of behavior listed in the ethogram (Table 3.1) were counted so that the proportion of turkeys performing each behavior could be calculated. In addition to the behaviors listed in the ethogram, the number of turkeys performing each of the following behaviors when interacting with the enrichment were also recorded: pecking at; standing, sitting, or resting on top of; hiding under; and jumping or walking and the number of turkeys at different locations (top; side; ramp; under).

Table 3.1. Ethogram of behavior, adapted from Dalton et al. (2018) and Duggan et al. (2014)

Behavior	**Description**
Gentle feather pecking (GFP)	Investigatory pecking without force and often causes no damage to the pecked turkey. It usually does not elicit a reaction from the recipient
Severe feather pecking (SFP)	Repeated, forceful pecking and pulling of the plumage and/or skin of another turkey, with or without feather removal, and often results in plumage and tissue damage to the recipient. The recipient may move away from the performer.
Aggressive pecking (AP)	Pecks that are usually targeted at the head, neck, and snood of another turkey
Environmental pecking (EP)	Pecking directed toward features of the housing environment (not including enrichments, feeders or drinkers)
Preening (PREEN)	Using the beak to manipulate its own feathers on the wings, back or breast
Interacting with enrichment (ENRICH)	Interacting with enrichment objects: either pecking at; or standing, sitting, or resting on top of; or hiding under/in; or jumping or walking (locomotion) on the enrichment

3.4 Statistical Analyses

All statistical analyses were performed using SAS software Version 9.4 (SAS Institute Inc., Cary, NC). Descriptive statistics for usage of different environmental enrichments at different ages and location of turkeys when interacting with enrichments have been provided in the results section. Raw data from scan sampling were first calculated as the average proportion of turkeys performing each behavior per hour on each recording day, then averaged across the two days of data collection at each age. Scan sampling data were subjected to repeated measures analysis using PROC GLIMMIX. Factors in the model included treatment (type of enrichment), age and their interaction. Pen nested in room was included as a random effect. Hour nested within age was the repeated measure. Environmental pecking, aggressive pecking, gentle feather pecking and severe feather pecking data were analyzed using a lognormal distribution and their results of least square (LS) means and standard errors (SE) were back transformed to the original scale. Results are reported as LS means $\pm$ SE or back-transformed LS means $\pm$ back-transformed SE. Post-hoc pairwise comparisons of LS means were examined using Tukey's test. Statistical significance was considered at $P \leq 0.05$.

3.5 Results

3.5.1 Turkey behavior

Usage of environmental enrichment

The average proportion of turkeys that interacted with environmental enrichment was significantly influenced by age ($F_{2,1041}$ = 7.41, P < 0.001; Fig. 3.1), treatment (enrichment type) ($F_{5,1041}$ = 96.32, P < 0.001; Fig. 3.2) and age × treatment ($F_{10,1041}$ = 3.58, P < 0.001; Fig. 3.3). The average proportion of turkeys that used environmental enrichments declined with age and was higher at 8 wk than at 12 wk (P = 0.035) and 16 wk (P < 0.001) (Fig. 3.1). The average proportion of turkeys that interacted with environmental enrichment was higher for the platform + straw bale group than the pecking block group (P < 0.001), platform group (P = 0.002), straw bale group (P < 0.001) and tunnel group (P < 0.001). The average proportion of turkeys that interacted with environmental enrichment was also higher in the platform group than the pecking block (P < 0.001), straw bale group (P < 0.001) and tunnel (P < 0.001) groups (Fig. 3.2).

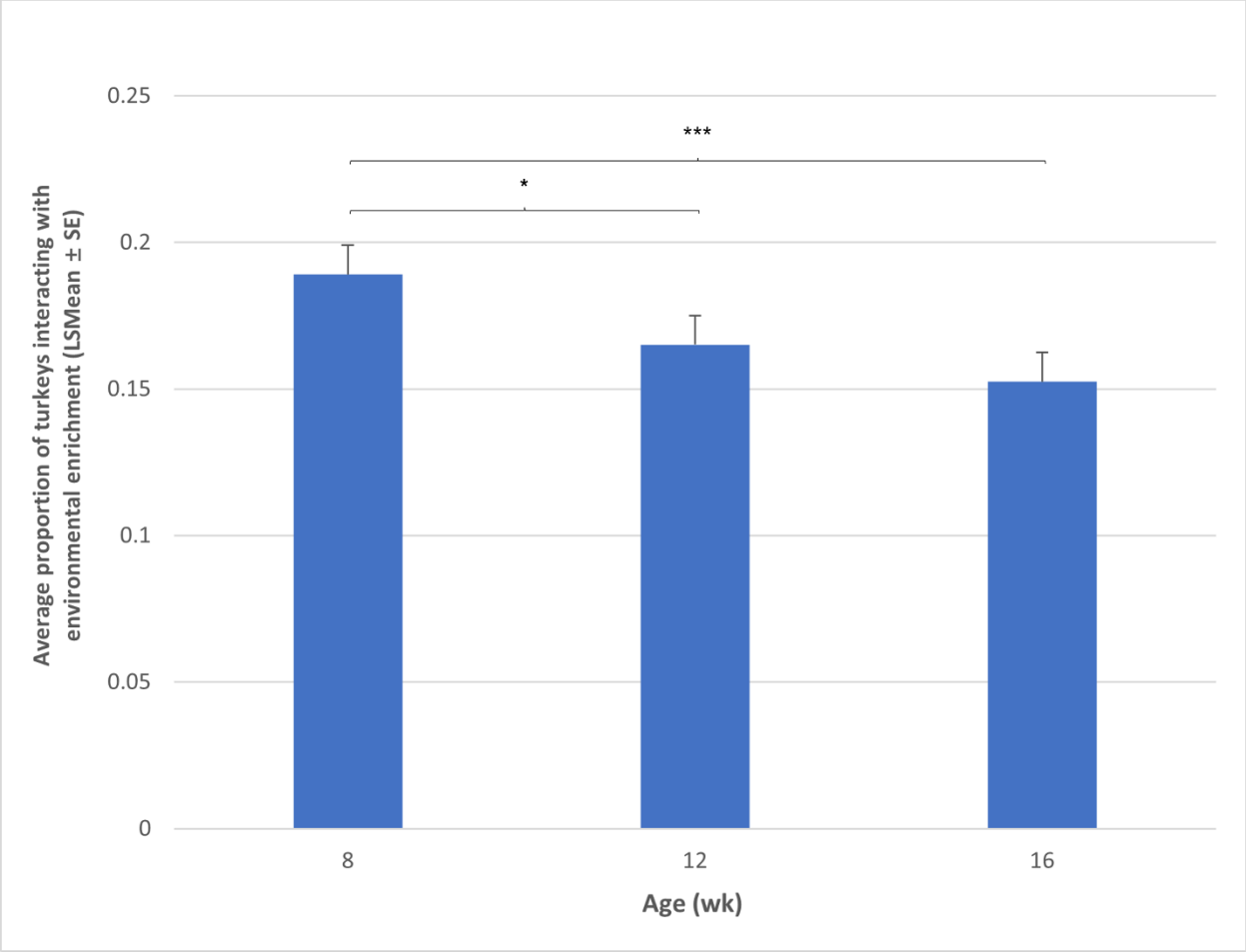

Figure 3.1. Average proportion of turkeys interacting with environmental enrichment (LSMean ± SE) at each age. * $P < 0.05$, *** $P < 0.001$

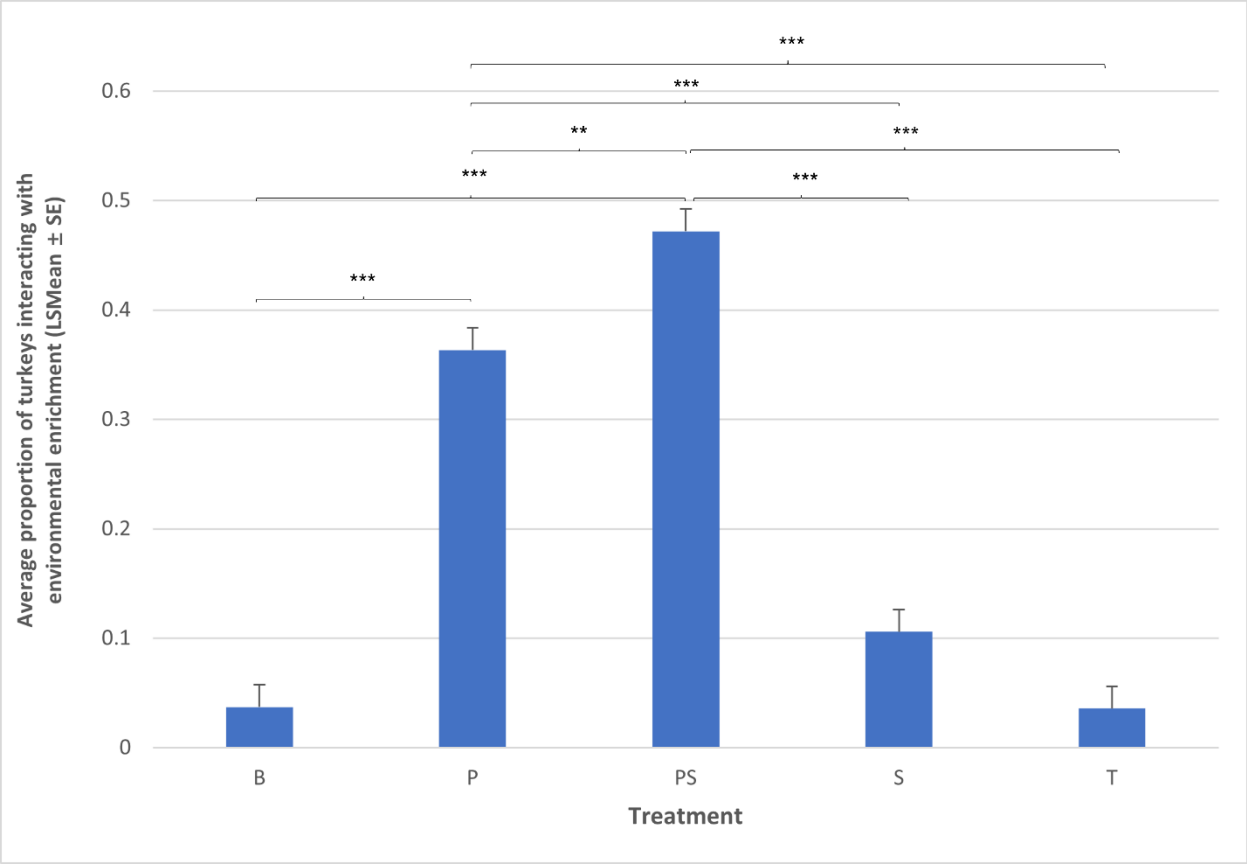

Figure 3.2. Average proportion of turkeys in each treatment group interacting with different types of environmental enrichment (LSMean ± SE). B = pecking block, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel. ** P < 0.01, *** P < 0.001

Across treatment groups, the average proportion of turkeys that interacted with environmental enrichment was highest in the platform + straw bale group (platform + straw bale vs. straw bale: P < 0.001; platform + straw bale vs tunnel: P < 0.001; platform + straw bale vs pecking block: P < 0.001; platform + straw bale vs platform: P = 0.002; platform + straw bale vs control: P < 0.001), followed by the platform group (platform vs straw bale: P < 0.001; platform vs tunnel: P < 0.001; platform vs pecking block: P < 0.001; platform vs control: P < 0.001). The average proportion of turkeys interacting with environmental enrichment declined with age in platform (8 vs 16 wk: P < 0.001) and pecking block groups (8 vs 12 wk: P = 0.044; 8 vs 16 wk: P = 0.02) (Fig. 3.3).

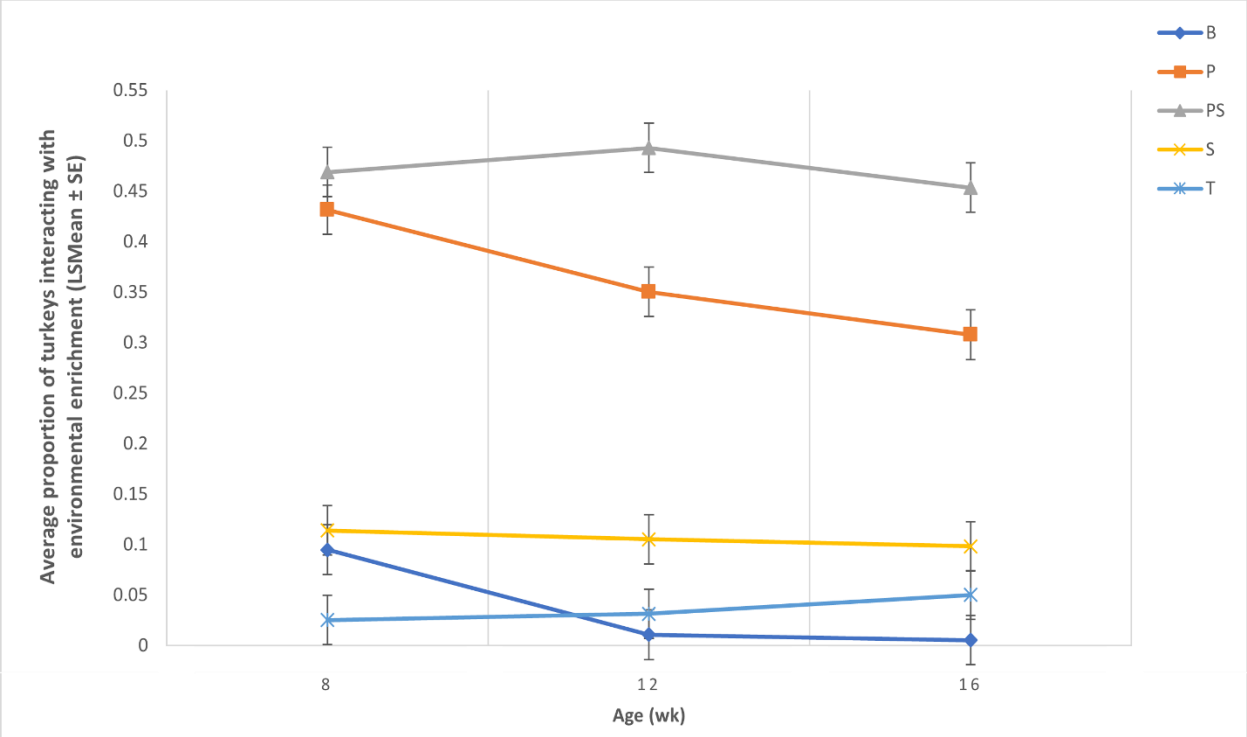

Figure 3.3. Average proportion of turkeys interacting with different types of environmental enrichment (LSMean ± SE) at each age. B = pecking block, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel

Preening

The average proportion of turkeys performing preening was not influenced by age ($F_{2,1041}$ = 2.22, P = 0.109; Fig. 3.4), treatment ($F_{5,1041}$ = 1.24, P = 0.288; Fig. 3.5) or age × treatment ($F_{10,1041}$ = 1.09, P = 0.368; Fig. 3.6).

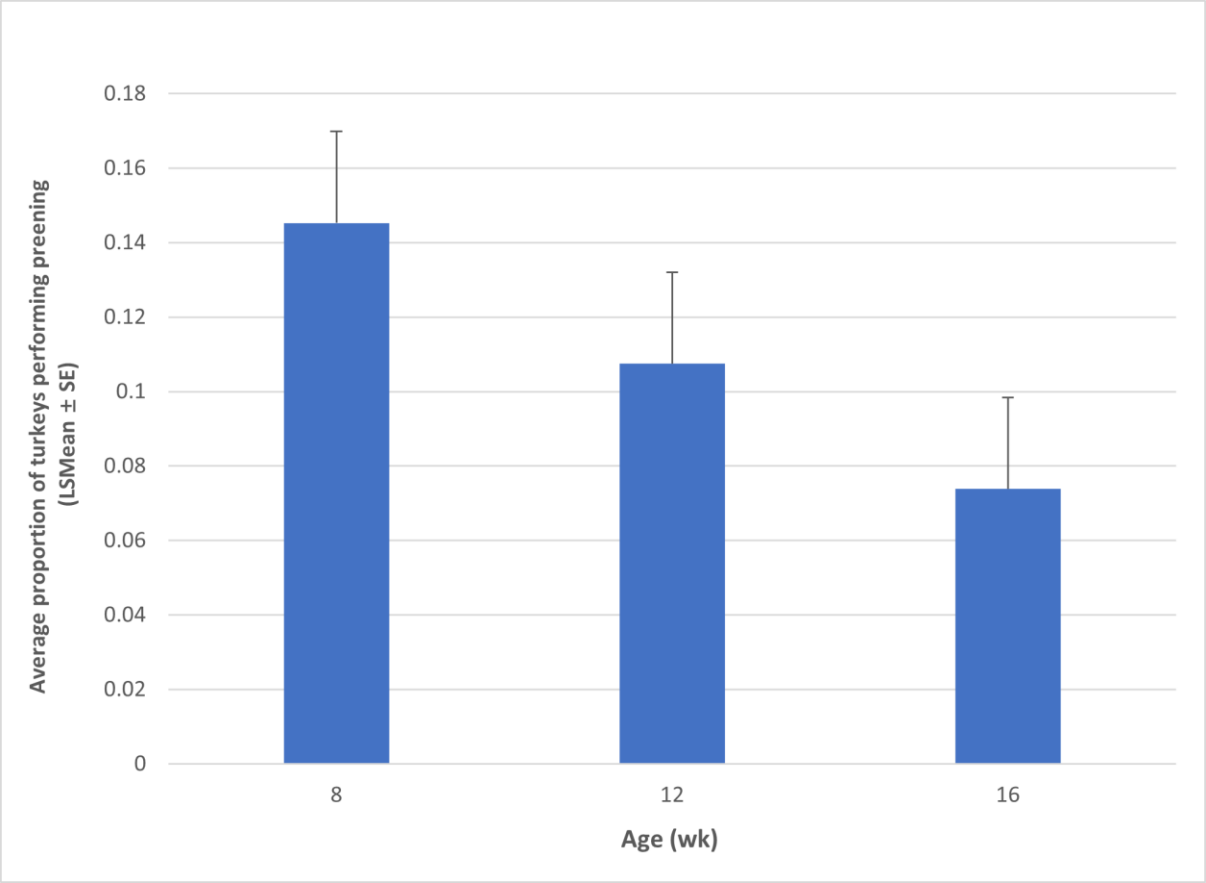

Figure 3.4. Average proportion of turkeys performing preening (LSMean ± SE) at each age.

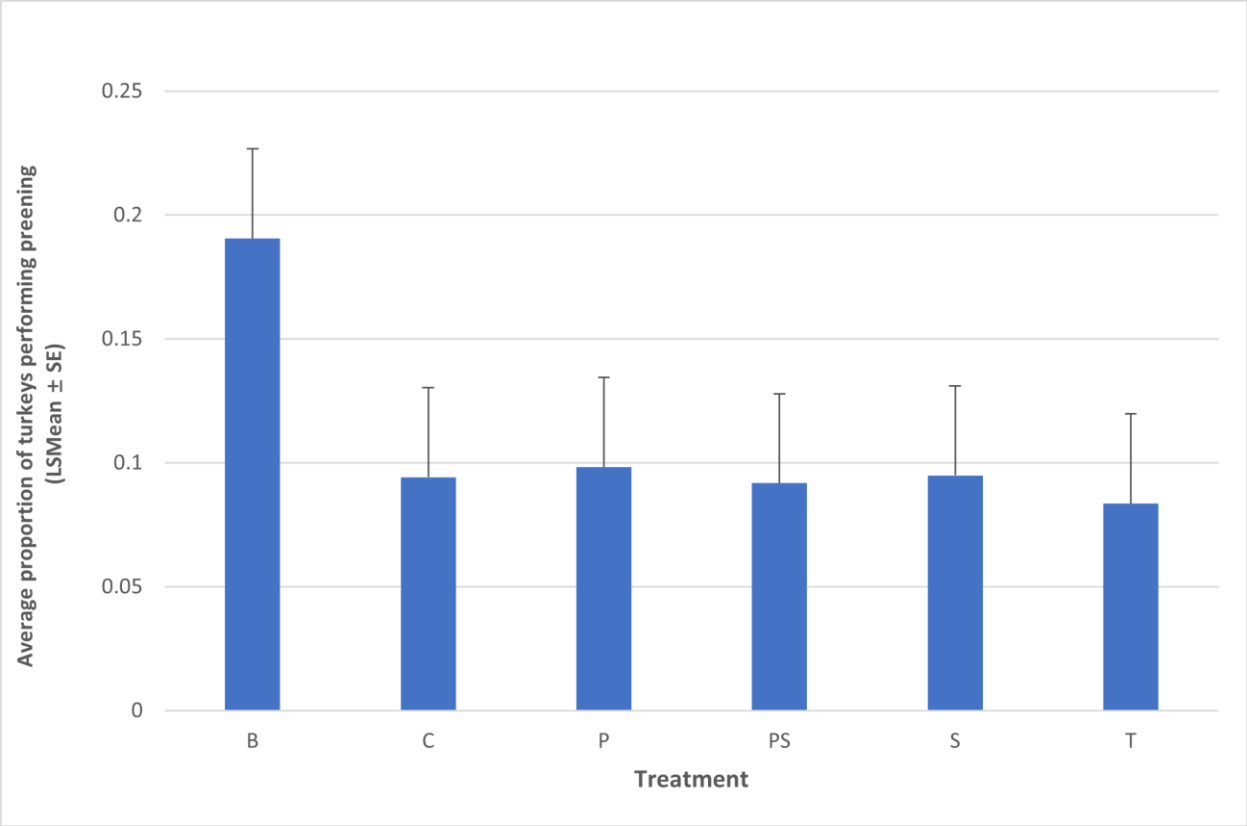

Figure 3.5. Average proportion of turkeys in each treatment group performing preening (LSMean ± SE). B = pecking block, C = control, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel.

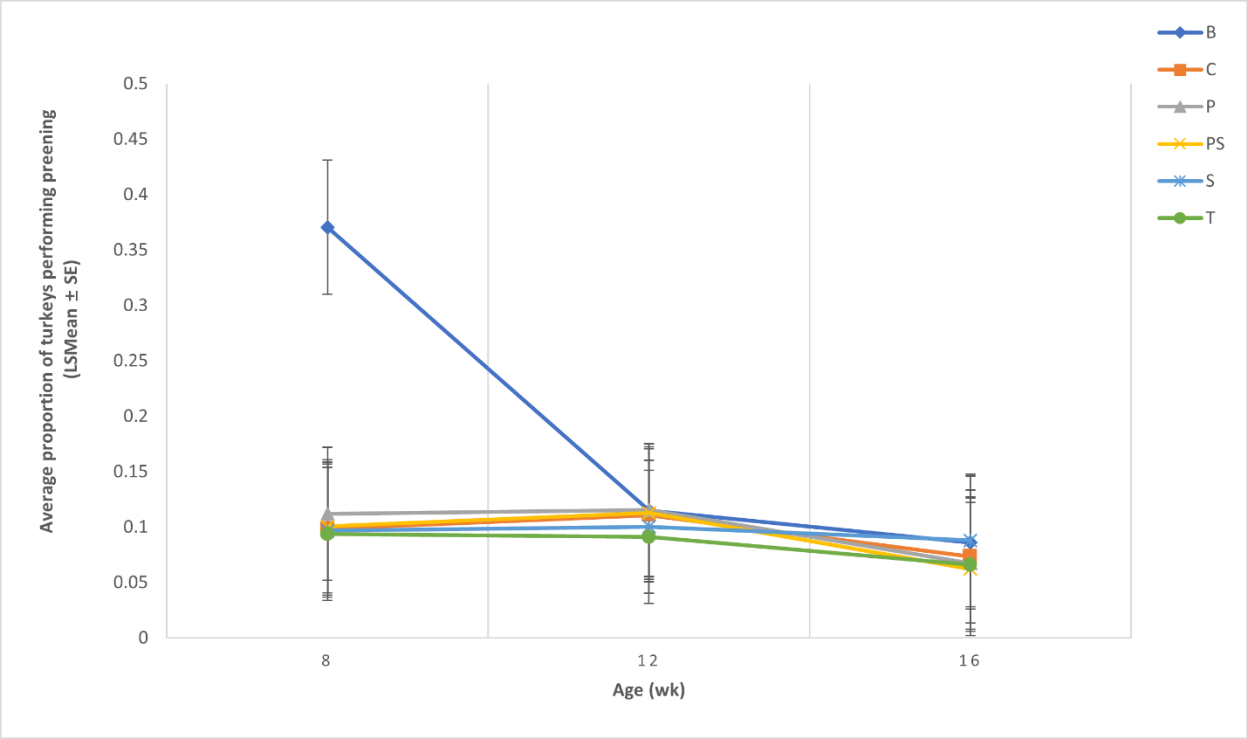

Figure 3.6. Average proportion of turkeys performing preening (LSMean ± SE) within each treatment group at each age. B = pecking block, C = control, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel.

Environmental pecking

The average proportion of turkeys performing environmental pecking was significantly influenced by treatment ($F_{5,1041}$ = 3.57, P = 0.003; Fig. 3.8) and age × treatment ($F_{10,1041}$ = 4.61, P < 0.001; Fig. 3.9), while age did not have a significant effect ($F_{2,1041}$ = 2.08, P = 0.126; Fig. 3.7). The average proportion of turkeys performing environmental pecking was higher in the control group than in the platform + straw bale group (P = 0.001), and did not differ among ages or other comparisons of enrichments.

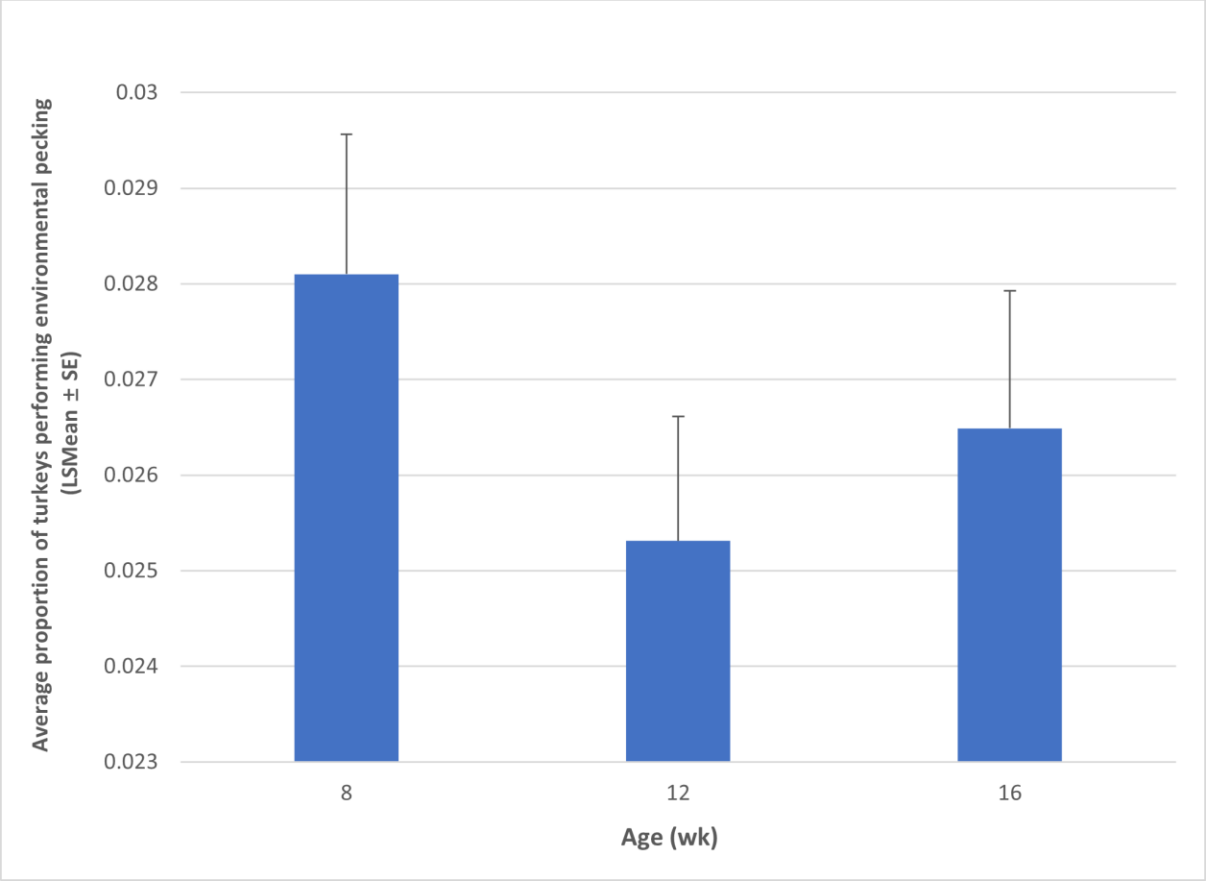

Figure 3.7. Average proportion of turkeys performing environmental pecking (LSMean ± SE) at each age.

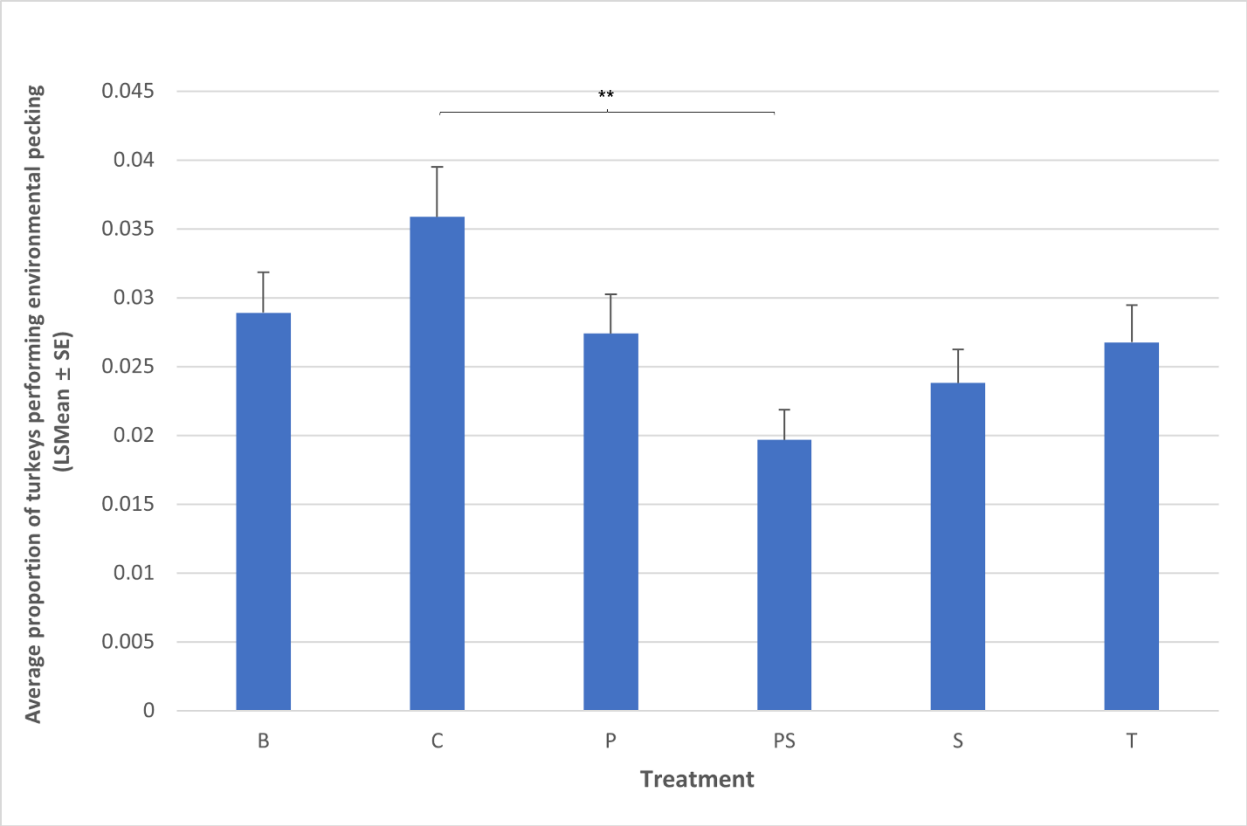

Figure 3.8. Average proportion of turkeys performing environmental pecking (LSMean ± SE) in each treatment group. B = pecking block, C = control, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel. ** $P < 0.01$

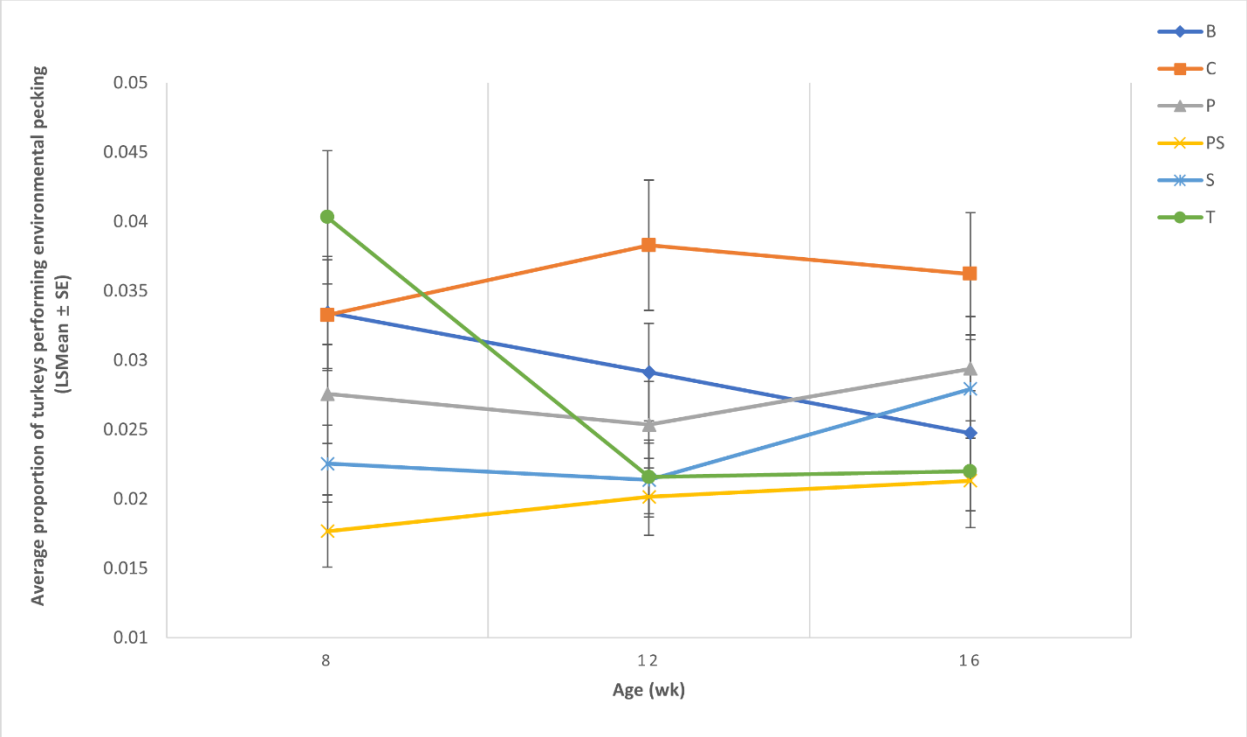

Figure 3.9. Average proportion of turkeys performing environmental pecking (LSMean ± SE) in each treatment group at each age. B = pecking block, C = control, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel. The average proportion of turkeys performing environmental pecking was higher at 8 wk than later ages in the tunnel group (8 vs 12 wk: P < 0.001; 8 vs 16 wk: P < 0.001).

Aggressive pecking

The average proportion of turkeys performing aggressive pecking was significantly influenced by age ($F_{2,1041}$ = 9.71, P < 0.001; Fig. 3.10), while treatment ($F_{5,1041}$ = 0.24, P = 0.943; Fig. 3.11); age × treatment ($F_{10,1041}$ = 1.46, P = 0.151; Fig. 3.12) did not have a significant effect. Aggressive pecking declined with age, which was higher at 8 wk than 16 wk (P < 0.001), and higher at 12 wk than 16 wk (P = 0.009).

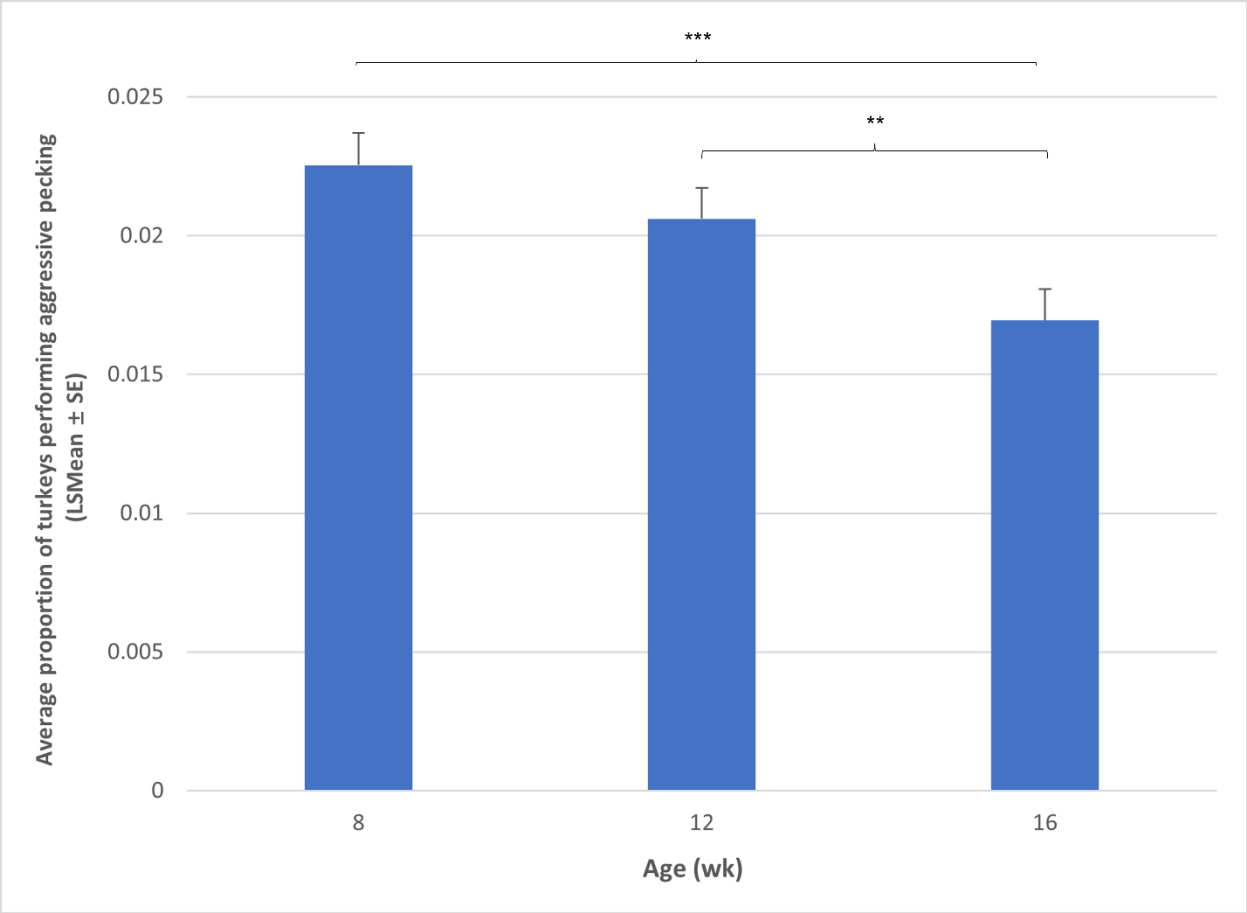

Figure 3.10. Average proportion of turkeys performing aggressive pecking (LSMean ± SE) at each age. ** P < 0.01, *** P < 0.001.

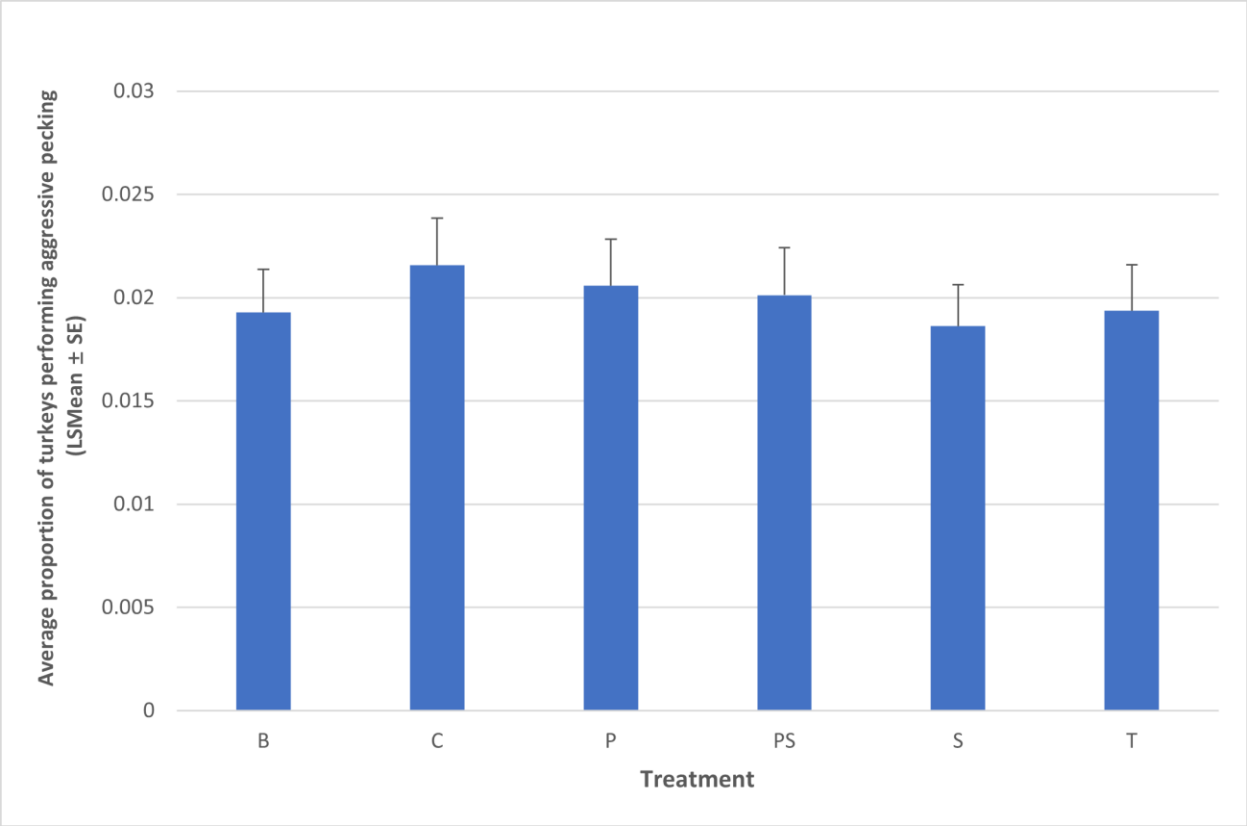

Figure 3.11. Average proportion of turkeys in each treatment group performing aggressive pecking (LSMean ± SE). B = pecking block, C = control, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel.

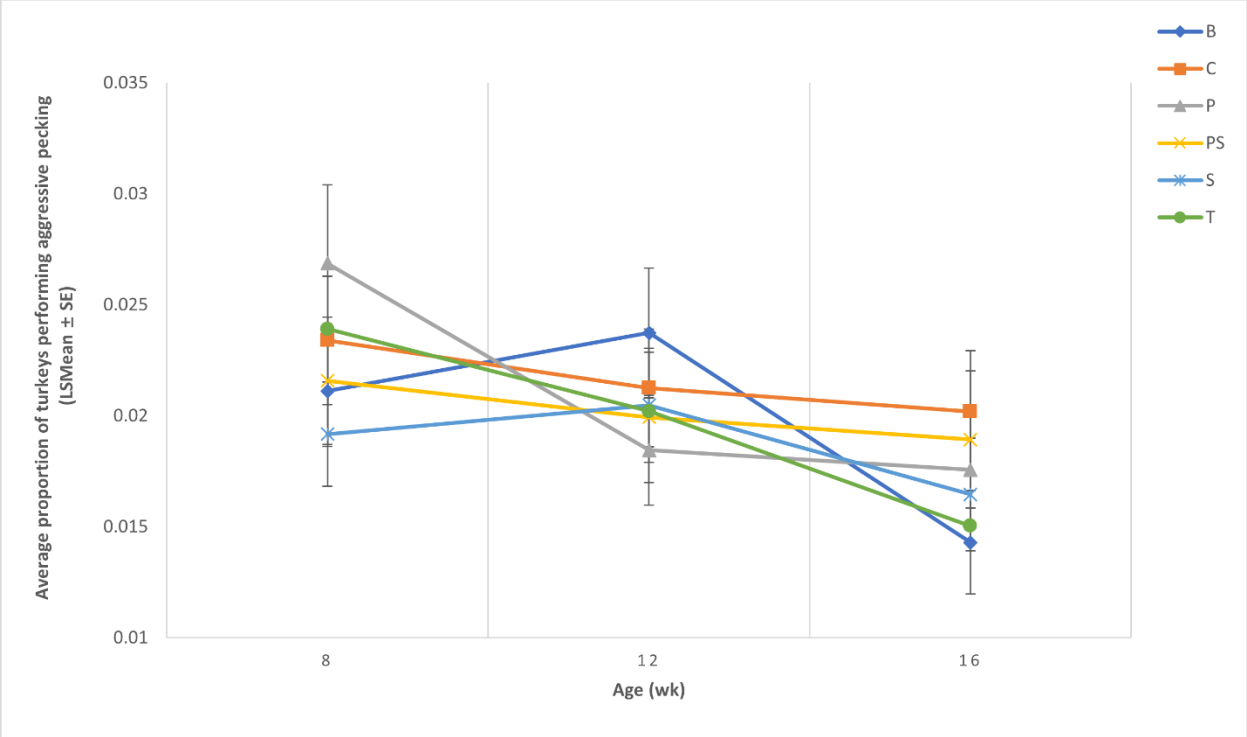

Figure 3.12. Average proportion of turkeys performing aggressive pecking (LSMean ± SE) in each treatment group at each age. B = pecking block, C = control, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel. No significant differences were found.

Gentle feather pecking

The average proportion of turkeys performing gentle feather pecking was significantly influenced by age ($F_{2,1041}$ = 8.94, P < 0.001; Fig. 3.13) and age × treatment ($F_{10,1041}$ = 3.52, P < 0.001; Fig. 3.15), while treatment ($F_{5,1041}$ = 0.92, P = 0.47; Fig. 3.14) did not have a significant effect. Gentle feather pecking was higher at 16 wk than 8 wk (P = 0.013) and 12 wk (P < 0.001).

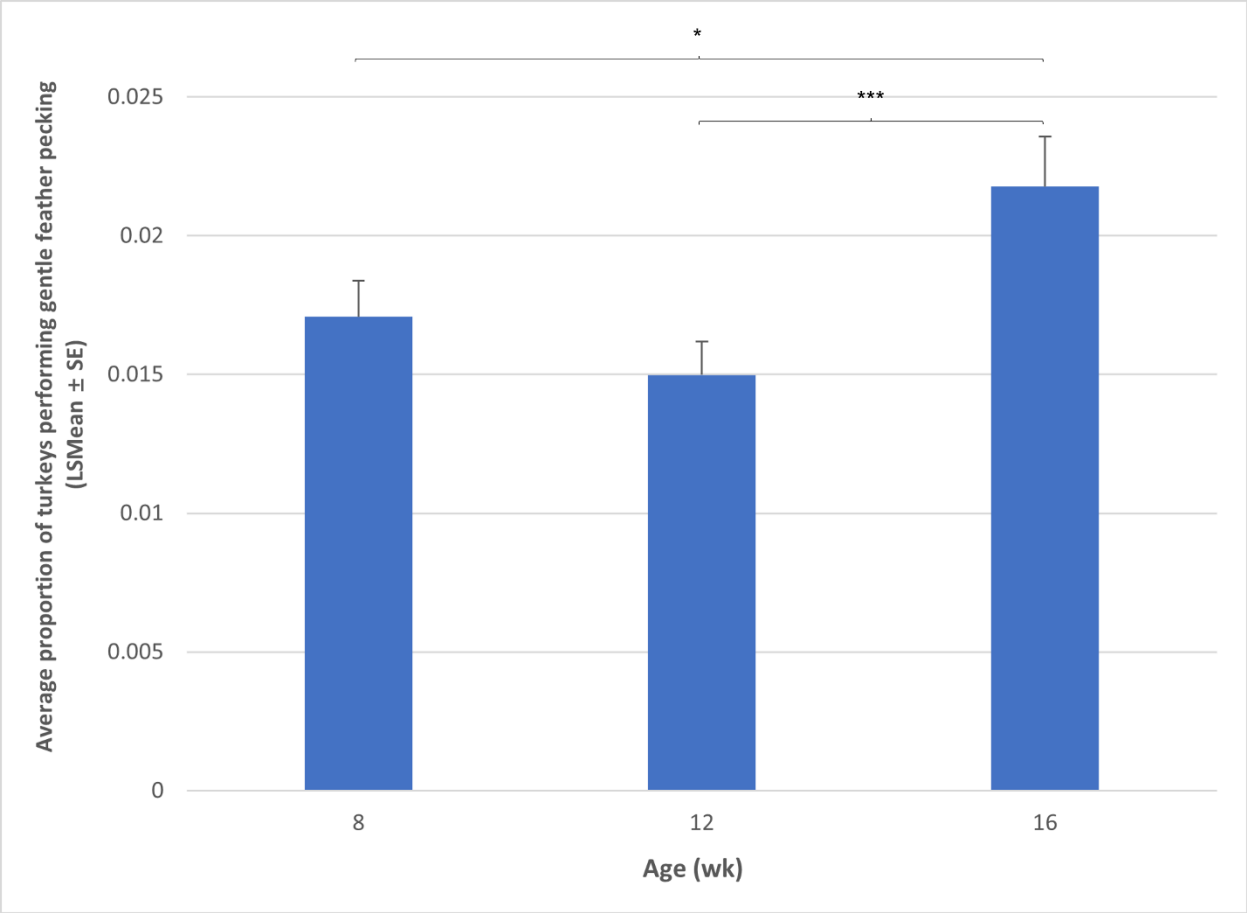

Figure 3.13. Average proportion of turkeys performing gentle feather pecking (LSMean ± SE) at each age. * $P < 0.05$, *** $P < 0.001$.

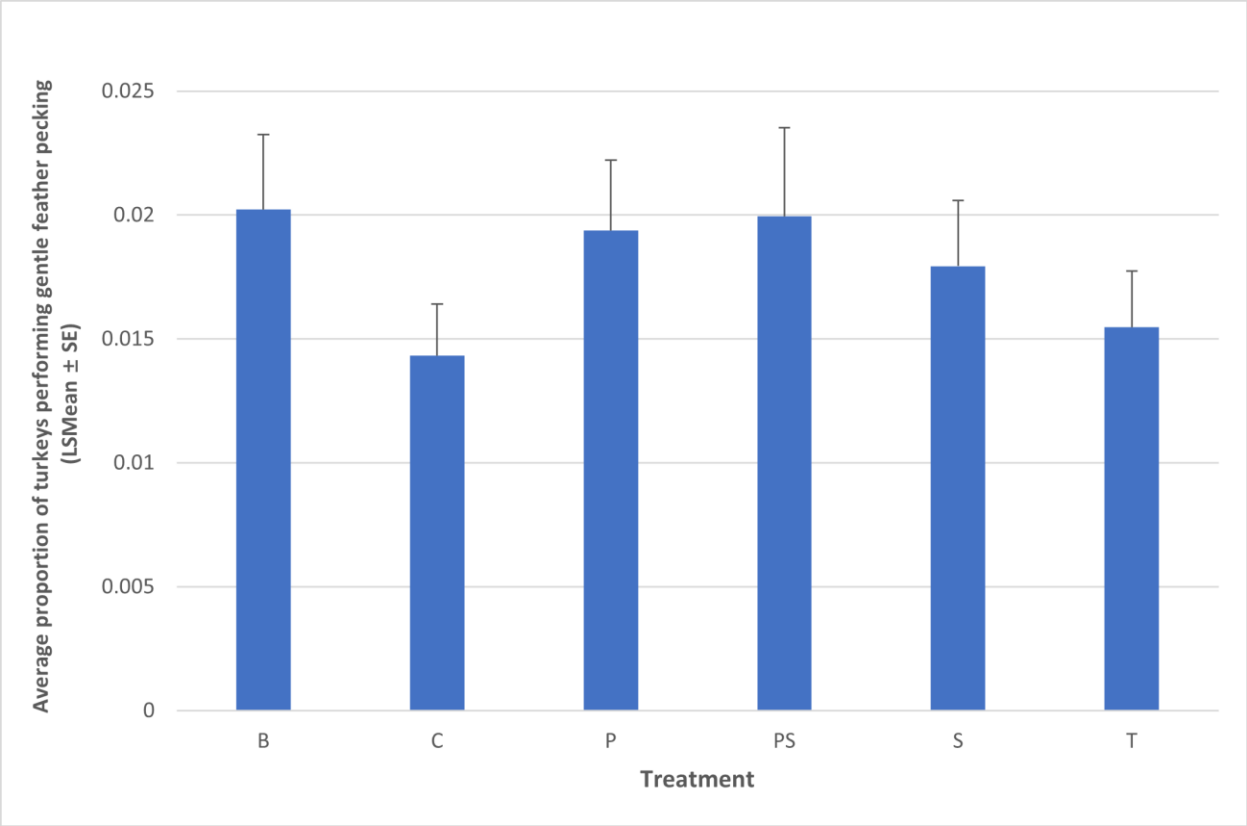

Figure 3.14. Average proportion of turkeys in each treatment group performing gentle feather pecking (LSMean ± SE). B = pecking block, C = control, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel.

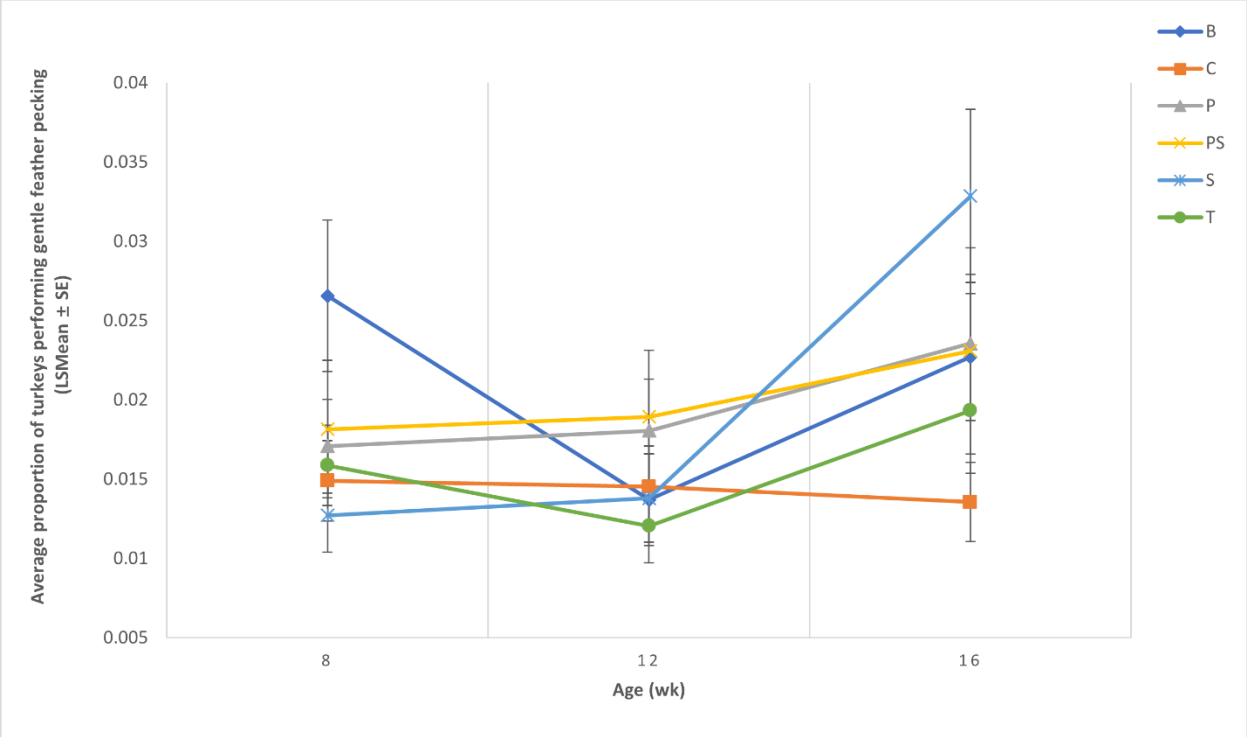

Figure 3.15. Average proportion of turkeys performed gentle feather pecking (LSMean ± SE) at each age. B = pecking block, C = control, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel. The average proportion of turkeys performing gentle feather pecking was lower at 12 wk than other ages in the straw bale group (8 vs 16 wk: P < 0.001; 12 vs 16 wk: P < 0.001).

Severe feather pecking

The average proportion of turkeys performing severe feather pecking was significantly influenced by age × treatment ($F_{10,1041}$ = 3.12, P < 0.001; Fig. 3.18), while age ($F_{2,1041}$ = 0.53, P = 0.591; Fig. 3.16) and treatment ($F_{5,1041}$ = 1.61, P = 0.155; Fig. 3.17) did not have a significant effect.

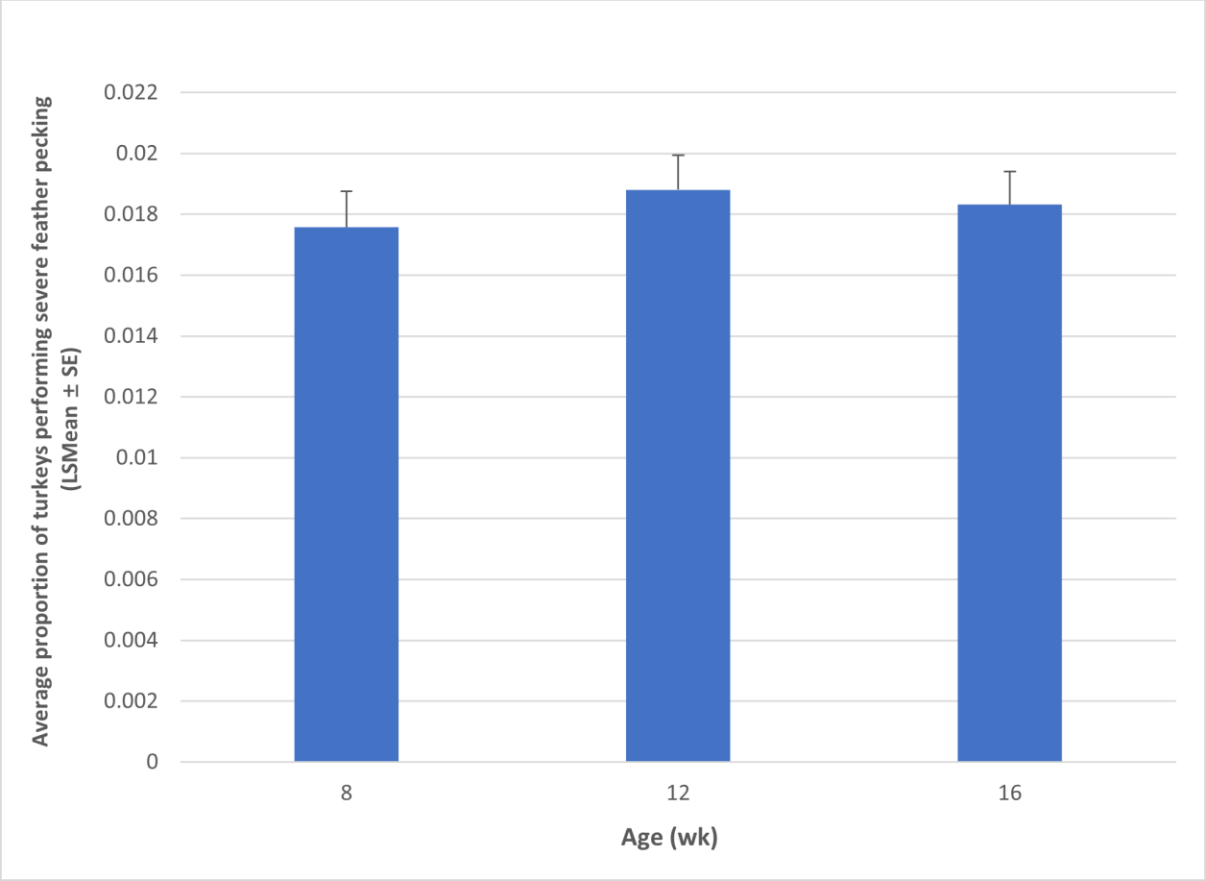

Figure 3.16. Average proportion of turkeys performing severe feather pecking (LSMean ± SE) at each age.

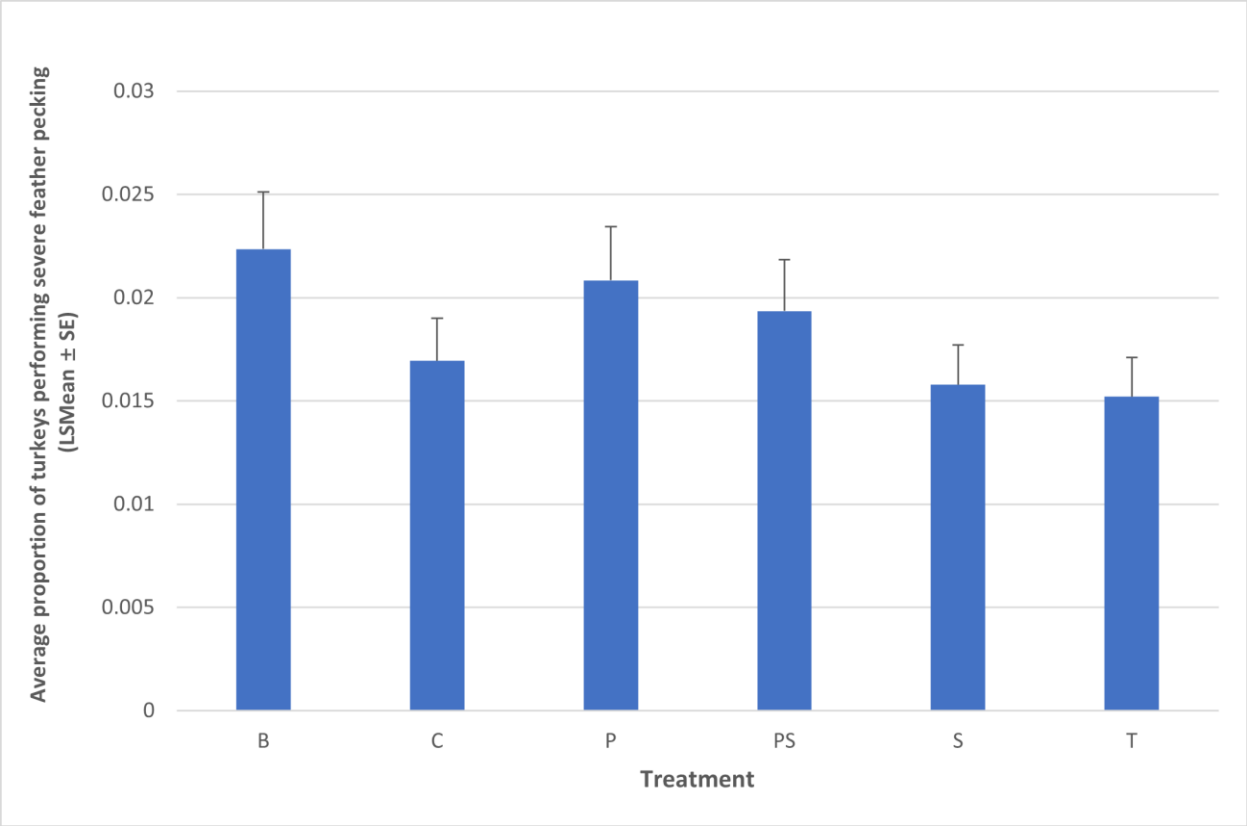

Figure 3.17. Average proportion of turkeys in each treatment group performing severe feather pecking (LSMean ± SE). B = pecking block, C = control, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel.

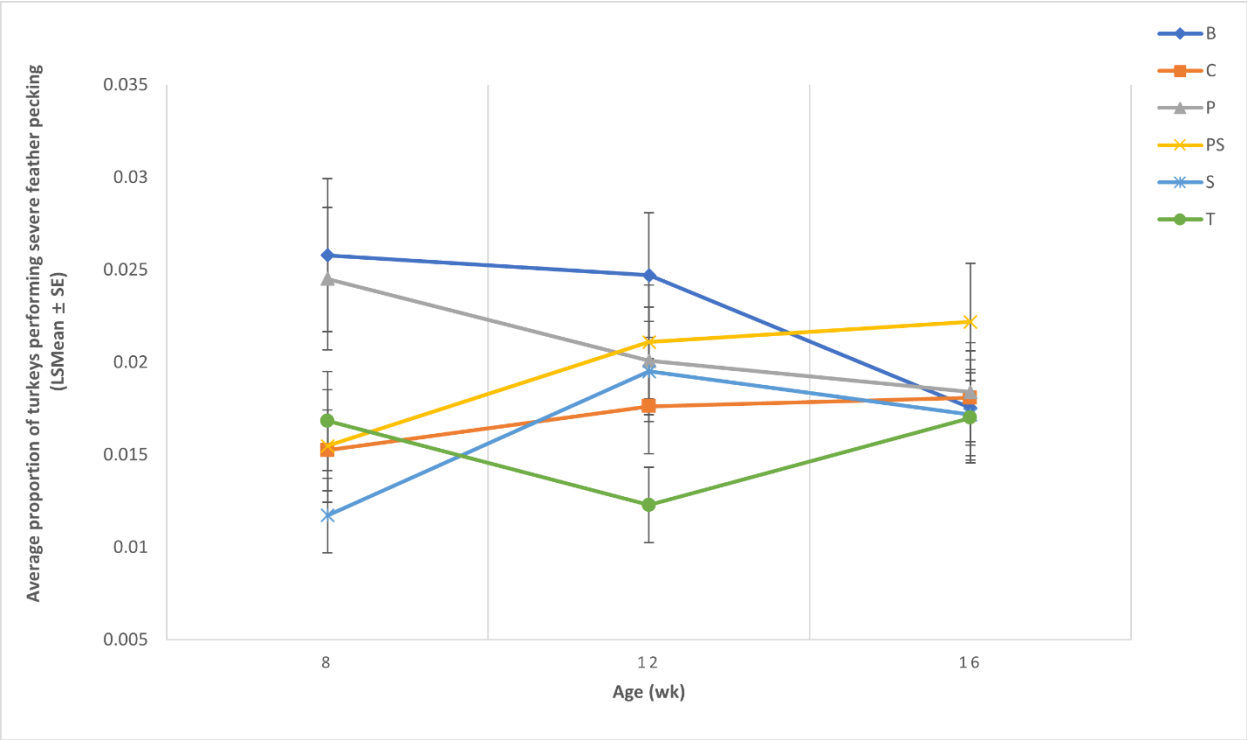

Figure 3.18. Average proportion of turkeys performing severe feather pecking (LSMean ± SE) at each age. B = pecking block, C = control, P = platform, PS = platform + straw bale, S = straw bale, T = tunnel. No significant differences were found.

3.5.2 Descriptive characteristics of enrichment usage

The enrichments used in this study could be used for different purposes (e.g. foraging, resting or pecking). In order to examine how turkeys used each enrichment, we determined how turkeys interacted with each enrichment in terms of whether they pecked at or rested on top of or under the enrichments, and the turkeys' location relative to the enrichment while they were interacting with that enrichment. To this end, we determined the percentage of observations wherein turkeys were interacting with each enrichment, but did not compare enrichments statistically because they were not all used for the same purpose. Therefore, comparisons of the types of interactions among enrichment types and locations of turkeys when using enrichments would not be meaningful.

Usage of different types of enrichments at different ages

How turkeys interacted with different types of enrichments at different ages is shown in Fig. 3.19. In the pecking block group, turkeys pecked at the block more frequently at 8 wk compared to later ages. Turkeys' interactions included standing, sitting, or resting on top of the pecking block across all ages. Turkeys jumped onto the pecking block more frequently with age. In the platform group, turkeys were either standing, sitting, or resting on top of the platform during observations. The percentage of observations when turkeys were jumping or walking on the platform was similar across different ages. Turkeys hid under the platform more frequently with age while they pecked at the platform less frequently with age. In the platform + straw bale group, turkeys' interactions included standing, sitting, or resting on top of the platform or straw bale. The percentage of observations during which turkeys were under the platform first decreased from 8 to 12 wk then increased from 12 to 16 wk. Turkeys jumped or walked on the platform or straw bale more frequently with age while they pecked at the platform less frequently with age. In the straw bale group, turkeys were either standing, sitting, or resting on top of the straw bale. The percentage of observations when turkeys were jumping or walking on the straw bale first decreased from 8 to 12 wk then increased from 12 to 16 wk. Turkeys pecked at the straw bale less frequently with age. In the tunnel group, turkeys were seen inside the tunnel at all ages, and the percentage of observations when turkeys were pecking at the tunnel, standing, sitting, or resting on top of the

tunnel, or jumping or walking on the tunnel first increased from 8 to 12 wk then decreased from 12 to 16 wk.

Location of turkeys when interacting with enrichments

The location of turkeys when they interacted with different types of enrichments at different ages is shown in Fig. 3.20. When interacting with enrichments in the pecking block and straw bale groups, turkeys were observed on the top of the enrichment across all ages or adjacent to the enrichment. Turkeys were observed to be on top of these enrichments more frequently as turkeys aged. In the platform and platform + straw bale groups, turkeys were observed on top of the enrichments when they were using the enrichments. The percentage of observations on the ramp first increased from 8 to 12 wk then decreased from 12 to 16 wk, and the percentage of observations adjacent to the enrichment in both groups decreased with age. The percentage of observations under the platform increased with age in the platform group, while first decreasing from 8 to 12 wk then increasing from 12 to 16 wk in the platform + straw bale group. For turkeys in the tunnel group, the percentage adjacent to the enrichment first increased from 8 to 12 wk then decreased from 12 to 16 wk. The percentage of observations in which turkeys were on top of the tunnel increased from 8 to 12 wk but no turkey was observed on top of the tunnel at 16 wk.

Figure 3.19. Depiction of how turkeys interacted with different types of enrichments at different ages presented as percentage of observations. Blue: located under/ in enrichment; orange: jumping or walking on enrichment; color: pecking at enrichment; green: standing, sitting, or resting on enrichment.

Figure 3.20. Location of turkeys when they interact with different types of enrichments at different ages presented as percentage of observations. Blue: ramp; orange: side; red: top; green: under/in.

3.6 Discussion

3.6.1 Influence of EE on turkey behavior

To the best of our knowledge, this is the first study to examine the effects of providing five different types of environmental enrichment on age-related changes in enrichment usage, injurious pecking, environmental pecking and preening behavior of turkeys. This study also investigated the specific behaviors directed at the enrichments and the relative location of the turkeys when they interact with different enrichments. Our results indicate that age had an overall effect on turkeys' interactions with enrichments, aggressive pecking and gentle feather pecking. Turkeys' usage of enrichment and performance of environmental pecking depended on the type of enrichment provided. Turkeys' overall average proportion of interactions with environmental enrichment declined with age. Our descriptive results indicated that turkeys provided with a platform + straw bale had the highest average proportion of enrichment usage overall, followed by turkeys provided with a platform as enrichment. In terms of specific behaviors observed, the average proportion of turkeys performing preening did not significantly change with age, or when provided with different enrichments. More turkeys in the control group performed environmental pecking compared to the platform + straw bale group. Aggressive pecking declined with age overall. Although not statistically significant, turkeys in the control group had a higher prevalence of aggressive pecking than enriched turkeys, with the straw bale group having the lowest prevalence and the pecking block and tunnel groups also having low prevalence of aggressive pecking compared to the rest of the treatment groups. The average proportion of turkeys performing gentle feather pecking was higher at 16 wk than earlier ages but not significantly different among treatments, with only numerically higher prevalence observed in all enrichment groups than the control group. The average proportion of turkeys performing severe feather pecking was not significantly different at different ages, or in different treatment groups, but was numerically lower in the straw bale and tunnel groups than the control group.

Interactions with environmental enrichment

Our observations of fewer turkeys using the enrichments with age was similar to a previous study on environmental enrichment in chickens (Baker et al., 2022). The gradual loss of interest in interacting with enrichments may be associated with the faster destruction of some types of

enrichments with age (e.g. straw bale and pecking block) and fecal contamination on the surface of the enrichments (Baker et al., 2022). Further work can be done using refinement of presentation of pecking or foraging enrichments such as straw bales to examine whether turkeys will better retain interest in those types of enrichments with age. Further, habituation is also an important factor causing enrichment objects to become less appealing to the animals under repeated or prolonged exposure (Domjan, 2000; Gallistel, 1990; Kuczaj et al., 2002; Oakes et al., 1991). When the same enrichment object is reintroduced after several days of absence, animals do not show as much interest as when the object is first introduced (Kuczaj et al., 2002). Further work can examine the effectiveness of periodic changes to the enrichment objects and use variable schedules of object presentation on the maintenance of turkeys' interest on the enrichments. However, it is useful to know whether turkeys' interest in these enrichments decreases over time, because it is labor intensive to change enrichments on commercial farms where thousands of birds are housed together.

Turkeys provided with a platform + straw bale and a platform as enrichment were the top two groups with the numerically highest average proportion of enrichment usage overall. These results may indicate that turkeys prefer multi-functional enrichments, as providing a platform or platform + straw bale as enrichment can serve multiple functions to satisfy different needs of the turkeys, including providing a place to rest, an elevated structure to perform locomotor activities, a pecking object and a shelter to hide from their conspecifics. In the wild, turkeys spend most of their daytime walking and foraging (including constantly pecking at items attracting their attention) and they roost on the trees especially at night to avoid predators (Kuvlesky et al., 2020; Mosby and Handley, 1943), and it follows that domesticated turkeys retain similar behavioral interests. In addition, turkeys spend large amount of time foraging and engaging in locomotion (walking or jumping) in captivity and in free-range systems (Irfan et al., 2016). Our observations of the specific behaviors when turkeys interacted with the platform or platform + straw bale were consistent with this assumption as turkeys performed all four types of behaviors (resting, locomotion, pecking and staying underneath the platform) when using those enrichments.

Preening

We observed that the average proportion of turkeys performing preening did not significantly differ between enrichments and the control group, which was similar to Lindenwald

et al. (2021) who reported that preening was comparable between their enriched group and control group. We also found an overall numerical decline in the average proportion of turkeys performing preening with age, which was also similar to the results reported by Lindenwald et al. (2021) and Sandilands and Savory (2002) that comfort behavior declined with age; however, differences in our study were not statistically different. Our observation of the higher average proportion of turkeys performing preening overall and especially at 8 wk in the pecking block group might indicate that turkeys did not interact much with the pecking block compared to other enrichment objects. Similarly, Crowe and Forbes (1999) reported a decrease in turkey preening activity when turkeys had increased pecking activity directed towards the enrichment objects.

Environmental pecking

We observed higher average proportion of turkeys performing environmental pecking in the control group than in the platform + straw bale group. A similar result was reported in Crowe and Forbes (1999) that turkeys provided with straw as enrichment performed increased pecking and foraging activities directed at the straw and decreased environmental pecking. Straw bales can be good substrates to fulfill turkeys' pecking and foraging needs (G.A.P, 2020; Sherwin et al., 1999b), as wild turkeys spend most of their daytime foraging by pecking at items attracting their attention or scratching and digging in the ground (Kuvlesky et al., 2020; Mosby and Handley 1943). We observed that the average proportion of turkeys that performed environmental pecking did not significantly change with age, which was also consistent with Crowe and Forbes (1999).

Aggressive pecking, gentle feather pecking and severe feather pecking

Aggressive pecking was found to decline with age, which was opposite to the findings of Sherwin et al. (1999b), who reported increased aggressive pecking in turkeys with age. The inconsistent result we observed may be related to the lower stocking density used in this study (2.15 – 2.42 birds/m^2), as stocking density can affect aggression in turkeys (Marchewka et al., 2013; reviewed in Erasmus, 2017). At higher stocking densities, levels of aggression can increase because birds cannot avoid aggressive encounters (Buchwalder and Huber-Eicher, 2004; Marchewka et al., 2013). The prevalence of aggressive pecking did not significantly differ between enrichments and the control group. Our result was different from previous studies that reported

lower prevalence of aggressive pecking when turkeys were provided with pecking substrates (Martrenchar et al., 2001) or visual barriers (Sherwin et al., 1999b). Similarly, the prevalence of gentle feather pecking and severe feather pecking also did not significantly differ among treatment groups. Gentle feather pecking usually causes no damage to the pecked turkey and is considered as a social and investigatory interaction between turkeys directed at the debris on the feathers (Dalton et al., 2018; Duggan et al., 2014; Savory, 1995). Previous studies in chickens suggested that certain level of gentle feather pecking may be a form of allopreening, which plays a part in social exploration and social bonds formation and maintenance (Blokhuis, 1986; Harrison, 1965; Riedstra and Groothuis, 2002; Vestergaard et al., 1993; Wood-Gush and Rowland, 1973). Our result was different from previous study that enrichments can provide more opportunities for birds to engage in exploration behaviors (Jones, 2001). On the other hand, severe feather pecking involves repeated pecking and pulling of the feather and/or skin and often leads to feather and skin damage (Dalton et al., 2018; Duggan et al., 2014). Our result was different from previous studies that fewer feather damage was found when providing turkeys with straw bales (Martrenchar et al., 2001; Sherwin et al., 1999b) or visual barriers (Sherwin et al., 1999b).

3.6.2 Specific behavior and relative location when turkeys interact with EE

Locomotion and gait

We observed increased locomotion (e.g. walking or jumping) with age in turkeys provided with a straw bale, platform, straw bale + platform or pecking block, while no locomotion behaviors (e.g. jumping on top of the tunnel) at 16 wk in the tunnel group. The delayed onset of gait problems in the straw bale, platform, straw bale + platform and pecking block group and earlier gait problem in the tunnel group may indicate a relationship between locomotion and gait. Previous research with broiler chickens suggested that providing straw bales or platforms were beneficial to the walking ability (gait) of broiler chickens because of their increased activity and locomotion (Bailie et al., 2013; Kaukonen et al., 2017). Further research will be needed to determine whether there is a relationship between locomotion and gait in turkeys.

Relative location of the turkeys

In order to further examine how turkeys use and interact with the different types of enrichment, we examined turkeys' position relative to the enrichments when they used the enrichments. Turkeys provided with a straw bale, platform, straw bale + platform or pecking block preferred to be on the top of the enrichment, which can contribute to overall increased locomotion and potentially delayed onset of gait problems in those enrichment groups that was observed in Chapter 2.

3.7 Study limitations

As our study was conducted on a research farm, there are several limitations that need to be considered when interpreting the results. The physical structure of the rooms limited the location to set up cameras in each pen, which made it not feasible to achieve 100% camera view coverage for the entire floor area. As the cameras were set to cover the area containing the enrichment objects, the number of turkeys performing behaviors unrelated to enrichments may actually be higher than observed because some birds could have been outside of the camera view. The stocking density of the turkeys in this study (2.15 to 2.42 birds/m^2) was lower than the commercial stocking density (2.5 to 3 birds/m^2) suggested in commercial management guidelines (Aviagen Turkeys, 2015) to ensure sufficient space for different enrichments. Stocking density can influence the level of aggression and feather pecking of turkeys because of limited space available to individual turkeys (Buchwalder and Huber-Eicher, 2004; 2005; reviewed in Erasmus, 2017). The pen size and the fixed locations of feeders and drinkers limited the placement of some enrichment such as the platform and platform + straw bale groups. Turkeys were potentially limited in their access to the enrichment objects from certain directions. Future research will be valuable in examining the variations in facilities that may better simulate conditions on commercial turkey farms. The number of enrichment objects provided in each pen may not be enough to avoid competition of enrichment usage; however, the ratio of enrichments to turkeys was higher than what is used in practice. For example, a minimum of two enrichment objects is recommended for every 93 m^2 of space (G.A.P, 2020). Some enrichment objects such as the pecking block, straw bale and tunnel only allow a small number of turkeys to use them at once. Other enrichment objects such as a platform and platform + straw bale can allow up to half of the turkeys in the pen to use

them at the same time. Further research will be necessary to investigate the number of enrichment objects needed based on the number of turkeys in the barn to achieve better outcomes in commercial settings. In addition, enrichment usage may differ among individual turkeys in the same pen, as some birds with higher dominance rankings may use enrichment objects more compared to subordinates. Future studies will be needed to examine enrichment usage in individual turkeys.

3.8 Conclusion

Turkeys showed high enrichment usage when provided with multi-functional enrichments that can fulfill different behavioral needs, with the combination of different enrichment objects (e.g., platform + straw bale) achieving the highest enrichment usage. Turkeys gradually lost interest in interacting with enrichments over time, which may be associated with habituation, destruction of some enrichment objects (e.g. straw bale and pecking block) and fecal contamination on the surface of enrichments. Further work examining the effectiveness of periodic changes to the enrichment objects and the implementation of unpredictable schedules of enrichment presentation will be valuable. Preening and severe feather pecking behavior did not change with age and were unaffected by the type of enrichment provided. Aggressive pecking and gentle feather pecking were not influenced by the type of enrichment provided. Under the conditions of this study, levels of injurious pecking were low, and there does not appear to be a single enrichment that was more beneficial than another in reducing injurious pecking behavior.

CHAPTER 4. CONCLUSIONS AND FUTURE DIRECTIONS

The objectives of this study were to investigate the effects of providing different types of environmental enrichment on turkey behavior, welfare and walking ability and provide more details about 1) age-related changes in welfare and gait when turkeys are provided with different types of environmental enrichment; 2) the effects of different types of environmental enrichment on enrichment usage and injurious pecking behavior; 3) specific behaviors and relative location of turkeys when they interact with different types of environmental enrichment.

In Chapter 2, welfare and gait assessments were conducted to study age-related changes in turkey welfare measures (wounds, feather quality, feather cleanliness, and footpad condition) and walking ability (gait) as influenced by different types of environmental enrichment. Environmental enrichment resulted in improved turkey wing feather quality, footpad condition and walking ability. Providing tom turkeys with straw bales and tunnels can help reduce wing feather damage with age and providing straw bales may reduce the prevalence of footpad dermatitis. Providing physical and occupational enrichments that provide more opportunities for activity and locomotion, including foraging or pecking enrichments (straw bale or pecking block) and elevated structures (bale or platform), may be beneficial for turkey walking ability.

In Chapter 3, video observations were conducted to study the effects of the enrichments on turkey behavior (enrichment usage, aggressive pecking, feather pecking, preening, and environmental pecking). Multi-functional environmental enrichment, especially a combination of enrichment objects, can promote turkeys' natural behaviors. Turkeys had the highest enrichment usage when provided with a combination of enrichment objects (e.g., platform + straw bale) that can serve multiple functions to fulfill their different behavioral needs. Providing a platform can also achieve high enrichment usage. Turkeys gradually lost interest in interacting with enrichments over time, which may be associated with habituation, destruction of some enrichment objects (e.g. straw bale and pecking block) and fecal contamination on the surface of enrichments. Specific behaviors that turkeys performed when using different types of enrichments are similar to the natural behaviors in wild turkeys, such as pecking at items that attract them, engaging in locomotion and resting on elevated structures.

Overall, providing enrichments that can fulfill turkeys' foraging and pecking needs can help reduce wing feather damage. Providing enrichment objects that can increase activity and

locomotion, such as elevated structures (straw bale or platform) and foraging or pecking enrichments (straw bale or pecking block) may help improve walking ability in turkeys. Providing turkeys with multi-functional enrichments that promote their natural behaviors, especially a combination of different enrichment objects (e.g., platform + straw bale) can help maximize enrichment usage. Future research will be valuable in examining the effects of implementing different types of environmental enrichment in various commercial facilities, and across different flocks and seasons. Further work is needed to investigate the effect of environmental enrichment on activity levels of turkeys and to determine whether there is a relationship between increased activity level and walking ability of turkeys. Further work examining the effectiveness of periodic changes to the enrichment objects and the implementation of unpredicted schedules of enrichment presentation on the maintenance of turkeys' interest on the enrichments will be valuable.

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