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Vegetation cover in outdoor enclosures reduces feather pecking in farm-reared red-legged partridges (*Alectoris rufa*)

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A R T I C L E I N F O

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A B S T R A C T

Feather pecking is a major problem in intensively reared birds, leading to welfare issues, chronic stress and economic losses. Despite the ample literature on how to improve the living conditions in the poultry industry, very little attention has been paid to gamebird species. The red-legged partridge (*Alectoris rufa*) plays a crucial role in the ecosystems of the Iberian Peninsula and also holds significant socio-economic importance in rural areas, as it is the primary species for small game hunting. Our aim was to experimentally test whether improved housing conditions with abundant natural vegetation cover reduce feather pecking and enhance body condition and growth in red-legged partridges. For two years, we compared the degree of feather pecking in red-legged partridges raised in two types of enclosures: a) in the absence of vegetation and b) with abundant natural vegetation. We also took morphometric measures (body weight and tarsus length) of the birds. We found that feather pecking varied both according to vegetation cover and bird age. Chicks aged between 42 and 67 days old exhibited a higher degree of feather pecking than adults. Vegetation cover reduced feather pecking in adults in one of the years of study and in chicks in the other. Additionally, we also found partial support that the presence of vegetation can improve body condition, as during one year, chicks raised in enclosures with vegetation were marginally heavier than those raised without vegetation. These findings suggest that the presence of vegetation might be a contributing factor in mitigating the development of abnormal behaviours in captive red-legged partridges. Future studies are necessary to evaluate what additional measures can be implemented to enhance the effectiveness of a vegetation enriched environment. Additionally, future studies should aim to investigate the effects vegetation cover in aviaries on other parameters relevant to the welfare of these birds, such as the physiological stress response and other specific behavioural traits.

1. Introduction

Gamebird farming is an growing industry around the world (Bilal, 2022; Geldenhuys et al., 2013; Thompson, 2007). In Europe, the main gamebird species are Galliforms (Martínez-Padilla et al., 2002; Sokos et al., 2008), which in many cases are subject to intensive commercial farming. This is the case of the red-legged partridge (*Alectoris rufa*), endemic species to the Mediterranean region, with both a high ecological and socioeconomic relevance (Arroyo and Beja, 2002; Farfán et al., 2022;). According to the Ministry of Agriculture, Fisheries, and Food almost 2 million Red-legged Partridges were released in Spain annually. However, some authors claim that since 2000 there has been an annual release of 4–5 million Red-legged Partridges (Gortázar et al., 2000; Arroyo and Beja, 2002; Farfán et al., 2022). These numbers rise significantly in other countries, such as the UK with 10 million per year (Aebischer, 2019), while France and Italy report lower numbers, at 2 million and 450,000 per year, respectively (Arroyo and Beja, 2002; Caro et al., 2014). In Spain, partridges for release are provided by more than six-hundred commercial farms of this species (Sánchez García-Abad et al., 2009). Although the vast majority of farm-bred partridges are intended for release, there is also a small hard-to-estimate number dedicated to meat and egg production. These farming practices have raised concerns due to genetic, sanitary, and welfare issues (e.g., Blanco Aguilar, 2007; Villanúa et al., 2008; Díaz-Sánchez et al., 2012). Maximizing productivity and profits should not overlook the potential harms of intensive farming, which need to be addressed and mitigated (Sánchez García-Abad et al., 2009; Sánchez-García et al., 2022).

One of the main problems associated to intensive bird farm-rearing is

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feather pecking (Dixon, 2008; Prieto et al., 2012; Cronin and Glatz, 2020; Fijn et al., 2020). Captive animals often exhibit agonistic and aggressive behaviours that include picking and pulling out the feathers on the back, tail or head of other individuals (Savory, 1995; Wysocki et al., 2010). Although a certain degree of mild feather pecking is normal to stablish dominance between individuals, intensive farming practices often lead to the exacerbation of this behaviour, causing tissue pecking on skin exposed patches, wounds that can become severe and even result in cannibalism (Savory, 1995; Dixon, 2008). Feather pecking behaviour has been linked to welfare issues in captive birds, reflecting chronic stress (Dixon, 2008; van Zeeland et al., 2009; Costa et al., 2016). Studies suggest that housing conditions, dietary deficiencies and the deprivation of the opportunity to perform natural behaviours such as foraging, dustbathing and perching, would lead to the arise of stereotypic behaviours (Huber-Eicher and Audige, 1999; Cronin and Glatz, 2020; Fijn et al., 2020; Nikolov and Kanakov, 2020). Despite this abnormal behaviour having been extensively studied in hens and other farm-reared birds (Colton and Fraley, 2014; Cronin and Glatz, 2020; van Staaveren et al., 2021), little attention has been paid to gamebird species such as the red-legged partridge. The few studies that do focus on it, have only examined aggression problems when pairing forced into small cages for reproduction (Alonso et al., 2008; Prieto et al., 2012). However, feather pecking is common among partridges kept in large outdoor aviaries during the first weeks and months of life. Investigating this abnormal behaviour is not only important for developing strategies to enhance the welfare of birds kept in captivity, but can also have important repercussions on the success of the released animals, as plumage quality, body condition and stress levels may be key for the survival of the birds and, therefore, for the success of restocking practices (Champagnon et al., 2012; Jones et al., 2017; Lamb et al., 2016). Furthermore, understanding and mitigating this issue can lead to a reduction in economic losses for gamebird farms and the meat production industry (Jones, 2001; Flock et al., 2005). Finally, addressing this welfare issue meets society's growing demand for ethical animal rearing. While poultry welfare standards have improved, gamebird farming lacks similar public and policy attention.

A key approach to improving captive animals' living conditions is environmental enrichment. It can be defined as the modification of the environments of captive animals to increase behavioural opportunities, to improve biological functioning and to reduce abnormal behaviours (Newberry, 1995; Shepherdson et al., 1999; Young, 2013). Including perches, foraging and dustbathing substrates and so forth, has been probed to enhance welfare, activity, and health for captive chickens, Pekin ducks and Japanese quails (Colton and Fraley, 2014; Laurence et al., 2015; Riber et al., 2018; Pedersen and Forkman, 2019; Pedersen et al., 2020; Ramankevich et al., 2022). However, there is a lack of studies in this matter regarding the red-legged partridge. Thus, the aim of this study was to examine whether improving housing conditions by including natural vegetation cover decreases feather pecking behaviour in red-legged partridges. We predicted that birds living in enclosures with abundant natural vegetation would have more opportunities to display natural behaviours such as foraging and sheltering, which would decrease the total time allocated to feather pecking (Mens et al., 2020). Moreover, we also expected that this might be reflected in morphometric parameters such as body size and weight, with red-legged partridges inhabiting enclosures containing vegetation during early life showing improved skeletal growth (i.e. tarsus length) and condition (i.e. weight). In this sense, we also wanted to test whether there were differences in feather pecking depending on the age and if the vegetation cover enrichment would yield different outcomes in adult-sized partridges and chicks. It would be expected that adult red-legged partridges would exhibit more severe symptoms of feather pecking, as they would have been exposed to a detrimental environment for a longer period, potentially leading to chronic stress and the development of ingrained stereotypies over time (Mason, 1993; Würbel et al., 1996; Vickery and Mason, 2004). Moreover, we predicted that this may result in a greater impact of the enrichment measures in the case of adult birds, because evidence in other galliforms show that chicks exposed to environmental enrichment exhibit significantly less feather pecking as adults (Huber-Eicher and Sebö, 2001).

2. Materials and methods

2.1. Study species

The Red-legged Partridge is a species endemic to the Mediterranean region, with a significant presence across southwestern Europe, including Portugal, Spain, France, Corsica, northern Italy, and western Germany (Farfán et al., 2022). The global population is estimated between 2 and 4.5 million pairs, with approximately 2.5 million pairs in the Iberian Peninsula (BirdLife International, 2004; Blanco Aguilar, 2007). In Spain, it is present from sea level to 2500 m in elevation, although it is less common in the Cantabrian Mountains and some other specific areas due to local climatic conditions or habitat suitability (Farfán et al., 2022). This species reaches sexual maturity at around one year of age, and exhibits some degree of sexual dimorphism in size (the typical weight range for adult males is approximately 400–550 gr, and 350–450 gr for females; Nadal et al., 2018) and in ornamental colouration (males exhibit redder eye rings and beaks and larger black areas in the flanks and necks than females; Bortolotti et al., 2006; Pérez-Rodríguez, 2008; Pérez-Rodríguez et al., 2013; Pérez-Rodríguez and Viñuela, 2008).

2.2. Study subjects and facilities

The study was carried out at the Dehesa Galiana experimental facility (Instituto de Investigación en Recursos Cinegéticos, Ciudad Real, Spain) during two consecutive years (2003 and 2004). Animals included in this study hatched from eggs produced by our captive reproductive population (ca. 100 breeding pairs). In both years, all birds used in this study came from a single incubation batch that hatched the 2nd July in 2003 and the 28th June in 2004. Hatchlings were kept in $2.0 \times 2.5 \times 2.25$ m (w × l × h) indoor enclosures with constant artificial tungsten light and two electric heaters, thus following usual procedures in commercial partridge farms. Water and commercial pelleted food specifically designed for partridges (Nanta Foods, Spain) was provided ad libitum throughout the study. During the first 3 weeks-chicks were fed with starter food, which was then switched to grower pelleted food until the end of the experiment; composition of both diets is reported in Table 1. When chicks were 15 days old, they were moved to two outdoor enclosures of $6.20 \times 14.0 \times 3.0$ m with a substrate of soil and small (ca. 1,5 cm diameter) stones. Both aviaries had 3 sheltered areas of $1.50 \times 1.80 \times 2.25$ m each and were identical in all aspects except that one of them had ca. 80 % of its surface covered by naturally grown vegetation (mostly composed by *Chenopodium vulvaria*, *Chenopodium* sp., *Lactuca serriola*, *Salsola kali*, *Heliotropium europaeum* and *Atriplex* sp.). The other aviary had no vegetation at all, as it was manually removed before birds were released. Between years, the vegetation treatment (i.e. vegetation or no vegetation) was swapped among enclosures in order to separate the effects of the aviary itself and the presence/absence of vegetation. The number of birds per aviary for each year is reported in Table 2. Bird densities ranged from 0.94 to 1.39 partridges/m^2, which is below the optimum of 3.46 birds/m^2 proposed for commercial rearing of the closely related rock partridge (*Alectoris graeca*) (Günlü et al., 2007). Also, densities are still below to those usually found in red-legged partridge farms destined to release and restocking, which often reach 2.5 birds/m^2 (David Risco, pers. comm.). When 1 month old, all birds were marked with numbered aluminium rings to allow individual identification. Mortality rate was extremely low during the study: only one bird died in 2003 (vegetation group) and two in 2004 (one in the control and one in the vegetation group, the later due to traumatism during capture at the aviary). Our study did not

Table 1
Composition of the starter and grower pelleted foods (Nanta Foods, Spain) provided to the partridges during the study.

Type of food	Starter (0–3 weeks)	Grower (3–13 weeks)
Components		
Protein (%)	27.4	21.8
Fat (%)	5.4	3.3
Fiber (%)	3.7	4.5
Ashes (%)	8.2	6.2
Calcium (%)	1.0	0.78
Phosphorus (%)	0.88	0.66
Sodium (%)	0.15	0.15
Additives		
Vit. A (UI/kg)	13000	10000
Vit. D3 (UI/kg)	1500	1500
Vit. E (mg/kg)	75	74
Calcifediol (mg/kg)	0.037	0.037
Choline chloride (mg/kg)	-	150
Fe (mg/kg)	40	40
Co (mg/kg)	0.20	-
Mn (mg/kg)	100	100
Zn (mg/kg)	80	80
I (mg/kg)	2.0	2.0
Cu (mg/kg)	15	15
Se (mg/kg)	0.25	0.20
Canthaxanthin (mg/kg)	9.0	12.7
Methionine (%)	0.36	0.40
Lutein (mg/kg)	-	16.37

Table 2
Number of partridges, densities, ages of sampling and sample sizes for the two experimental rearing conditions (outdoor aviaries with or without vegetation) in each of the study years (2003 and 2004).

Year	2003		2004	
Type of outdoor aviary	Vegetation	No Vegetation	Vegetation	No Vegetation
Number of birds	91	82	111	121
Density (birds/m^2)	1.05	0.94	1.28	1.39
Age at chick sampling	42 days-old		67 days-old	
N of chicks sampled	42	40	40	36
Age at adult-sized sampling	115 days-old		121 days-old	
N of adult-sized birds sampled	60	47	37	36

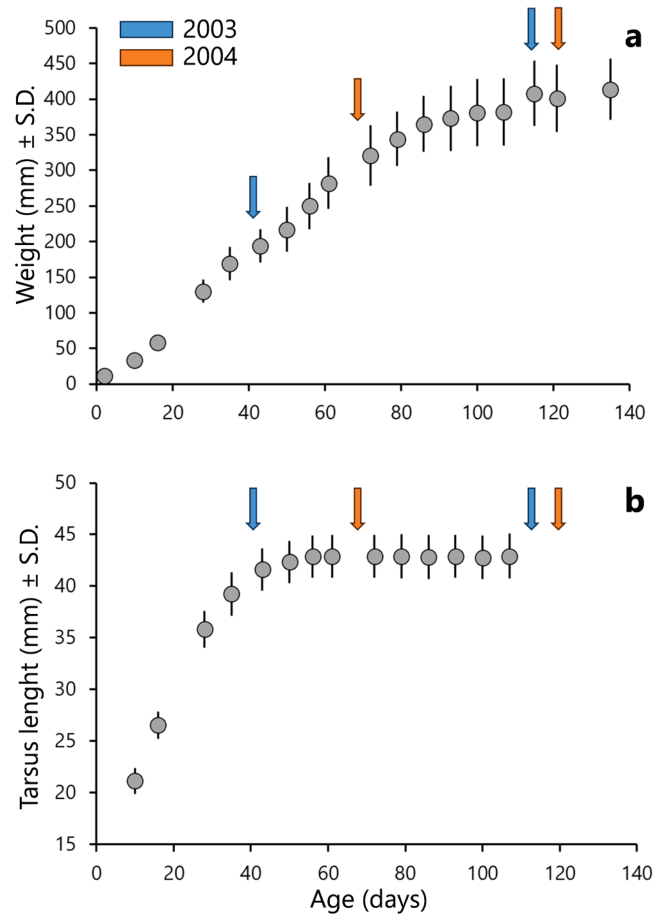

Fig. 1. Typical pattern of a) body weight and b) tarsus length increase with age in captive red-legged partridges. Data (means± S.D.) belong to 66 birds of a different cohort to those used in this study but are illustrative of the age-related pattern in our captive population. Blue and orange arrows indicate the sampling points for feather pecking plumage damage, body weight and tarsus length of this experiment in 2003 and 2004, respectively.

involve procedures subject to prior review by the Ethics Committee for Experimentation of our institution, according to the criteria of Spanish laws (RD 53/2013). However, our study protocol and the welfare and health state of the birds were supervised by the veterinary staff of the Instituto de Investigación en Recursos Cinegéticos (IREC), which guarantees that national and international standards of welfare in animal farming and husbandry are met.

2.3. Data collection

In order to quantify the impact of vegetation on morphometric variables and on the degree of feather pecking, we randomly captured a sample of birds of each aviary twice per year. The exact ages and number of birds sampled slightly differed between years (Table 2). However, in both years the first sampling was performed when the chicks had reached their asymptotic tarsus length and were still in their linear phase body weight increase (Fig. 1) and were still moulting their juvenile plumage into the adult-like plumage (Fig. 1S). The second sampling was performed when birds had reached their adult tarsus length and body weight (Table 2, Fig. 1) and displayed their characteristic adult plumage (Fig. 2S). At each sampling event, a random subsample of the birds of each aviary was captured and we measured their tarsus length to the nearest 0.01 mm with a digital calliper and recorded their body weight to the nearest gram. Birds were then immobilized in a standard position to take a photograph of their back to quantify the degree of feather plucking damage (Supplementary material SM1 Figs. 1S and 2S) and were released back to their aviary.

To measure the area affected by feather pecking, we analysed the pictures through the Adobe Photoshop CC 2022 software (Adobe Inc., 2019). Using magic the wand tool, we measured the number of pixels of both total visible dorsal area and the portion of it where feathers had been plucked, and then calculated the percentage of dorsum with feathers plucked as a measure of intensity of feather pecking received by each bird.

2.4. Statistical analysis

Because the ages of the birds were not the same in the two years of study, we performed separate analyses for 2003 and 2004. To analyze differences in feather pecking depending on vegetation cover and age, we conducted two Generalized Linear Mixed Models (GLMM) with a Gaussian distribution and identity link. The response variable for both models was the percentage of the dorsal region where feathers had been plucked. Since the response variable was a proportion, we applied the arcsine square root transformation (Mordkoff, 2016). The explanatory categorical variables included in the models were the vegetation cover of the enclosures (with vegetation / without vegetation), the age of the

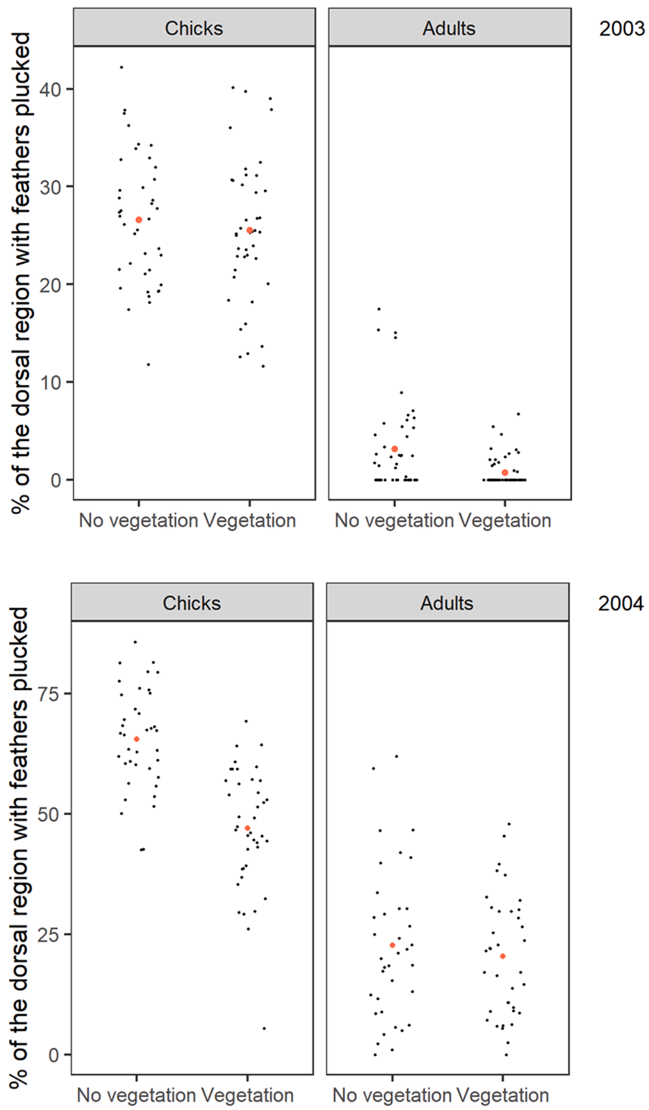

Fig. 2. Percentage of the dorsal part of the body affected by feather plucking (measured in pixels) in chicks and adults depending on the vegetation cover during 2003 (above) and 2004 (below). The red dot indicates the mean. Note the different scales of the y-axes between years.

animals (chick / adult-sized), and the interaction between them. Given that, at each sampling event, birds sampled were a random subsample of those available in each experimental aviary, and some birds were sampled both as chicks and as adults, we included individual identity as a random effect to account for the non-independence of the data.

To compare differences in bird weight and tarsus length depending on the vegetation cover of the enclosures, we performed separate GLMMs for each trait and year, also with a Gaussian distribution and identity link. As above, the models included the type of enclosure (with vegetation / without vegetation), the age of the birds (chick / adult-sized), and the interaction between them as fixed effects, while the individual identity was included as a random effect. Post hoc comparisons were performed using Tukey tests via estimated marginal means (emmeans package) to assess pairwise differences between levels of the factors. The sex of the birds was not considered in any of the analyses because it was unknown. Results were considered significant at $\alpha < 0.05$. All statistical analyses were performed using R version 4.4.1 (R Core Team, 2023) and the packages lme4 (Bates et al., 2015), emmeans (Lenth, 2022), and car (Fox and Weisberg, 2019). Figures were generated using the ggplot2 package (Wickham, 2016).

3. Results

3.1. Feather pecking

We found that, in both years, the area damaged by feather pecking in red-legged partridges varied significantly depending on age, vegetation cover and the interaction between both (Table 3). The mean dorsal feather plucked area in red-legged partridges was consistently higher in chicks than in adult-sized individuals (Fig. 2, Table 4). For vegetation cover, post hoc Tukey comparisons showed that in 2003, feather pecking damaged area was significantly lower in enclosures with abundant vegetation for adults (estimate = 0.087, SE = 0.019, $p < 0.001$), but not for chicks (estimate = 0.014, SE = 0.021, $p = 0.9125$). In 2004, we also found lower feather pecking levels in the enclosure with vegetation, but only among chicks (estimate = 0.194, SE = 0.035, $p < 0.001$; adults estimate = 0.0172, SE = 0.0373, $p = 0.9674$).

3.2. Weight and tarsus length

The mean weights and tarsus lengths of the birds of this study are shown in Table 4. Body weight consistently increased from chicks to adult-sized individuals in both study years (Table 3). However, whereas in 2003 we found no effect of vegetation cover on partridge weights, either alone or in interaction with age, in 2004 we found a significant interaction between age and vegetation cover (Table 3). The post hoc test revealed that in 2004 chicks tended to be lighter in the aviary with no vegetation cover compared to the aviary with vegetation, although differences did not reach the significance threshold (estimate = −18.26, SE = 7.72, $p = 0.0885$). However, this trend disappeared when the birds reached their adult phenotype (estimate = 2.23, SE = 7.97, $p = 0.9923$). We did not find significant effects of vegetation cover, age, or their interaction on the tarsus length of partridges in any of the study years (Table 3).

4. Discussion

4.1. Feather pecking

Our results show that including abundant vegetation cover in enclosures as an environmental enrichment measure may reduce the severity of feather pecking in captive red-legged partridges. This finding

Table 3
Results of the GLMMs analysing the effect of the age (chicks vs. adults) and the vegetation cover (no vegetation vs abundant natural vegetation) and their interaction on the degree of feather pecking suffered (measured as the proportion of dorsal with feathers plucked), body weight and tarsus length of red-legged partridges in the years of study (2003 and 2004). Individual identity was entered as a random effect in all models.

	Year 2003			Year 2004		
	F	d.f.	p	F	d.f.	p
Feather pecking						
Age	1115.5221	1	< 0.001	273.577	1	< 0.001
Vegetation	14.1735	1	< 0.001	16.317	1	< 0.001
Age × Vegetation	7.2791	1	< 0.01	14.195	1	< 0.001
Weight						
Age	897.6266	1	< 0.001	442.5130	1	< 0.001
Vegetation	1.1552	1	0.2848	1.6891	1	0.19618
Age × Vegetation	0.0228	1	0.8801	5.7637	1	0.01969
Tarsus length						
Age	1.201	1	0.273	0.5266	1	0.4710
Vegetation	0.0137	1	0.90712	1.3813	1	0.2422
Age × Vegetation	0.0680	1	0.79528	1.8752	1	0.1762

Table 4
Weights, tarsus lengths and percentage of dorsal feather pecking (means ± S.E.) of chicks and adult-sized birds according to the presence or absence of vegetation in the outdoor aviaries for the two years of study (2003 and 2004).

Year	Age	Vegetation cover	Weight (g)	Tarsus (mm)	% of feather pecking	N
2003	Chicks 42 days	No vegetation	211.7 ± 4.03	41.95 ± 0.22	26.58 ± 1.06	40
		Vegetation	219.6 ± 4.26	41.92 ± 0.30	25.51 ± 2.89	38
	Adults115 days	No vegetation	397.0 ± 9.09	41.50 ± 0.28	3.15 ± 0.66	47
		Vegetation	403.6 ± 6.36	41.46 ± 0.43	0.69 ± 0.19	40
2004	Chicks 67 days	No vegetation	268.5 ± 4.74	42.69 ± 0.26	65.54 ± 1.63	40
		Vegetation	291.9 ± 5.63	42.65 ± 0.35	46.97 ± 2.00	40
	Adults 121 days	No vegetation	375.1 ± 6.27	43.16 ± 0.30	22.71 ± 2.65	38
		Vegetation	365. 8 ± 7.30	42.25 ± 0.33	20.44 ± 2.07	37

supports our hypothesis that enclosures with abundant natural vegetation provide greater opportunities for the development of normal behaviours (i.e. foraging, sheltering), reducing the frequency of stereotypies. This result is in line with previous reports confirming the benefits of including environmental enrichment, and specifically vegetation cover, for captive domestic and wild animals (Riber et al., 2018; Lemos de Figueiredo et al., 2021; Alejandro et al., 2022; Jacobs et al., 2023). However, our results did not follow our prediction that adult individuals would be more affected by this maladaptive behaviour, as individuals beyond 4 months-old consistently showed consistently lower levels of feather damage than chicks of 6–10 weeks-old. One possible explanation could be that younger individuals had higher or more specific nutritional demands as they were in a phase of somatic growth (Jahanian, 2009; Ravindran and Abdollahi, 2021). On the other hand, the development of exploratory and affiliative behaviours takes place during this stage, which could result in an increase in pecking frequency among chicks as compared to older individuals (Riedstra and Groothuis, 2002; Chow and Hogan, 2005). In particular, the molt from juvenile to adult plumage in red-legged partridges takes place between 40 and 70 days old (Pérez-Rodríguez, pers. obs.). During this phase, animals could have greater or special energetic demands associated to feather growth, and nutrient deficiencies or imbalances could lead to feather pecking (Kjaer and Bessei, 2012; Mens et al., 2020). Furthermore, when new feathers are growing, quills are very prominent, which could be an attractive stimulus, and the soft and highly vascularized sheath of growing feathers may further elicit pecking behaviour from conspecifics.

However, when we analysed the reduction in feather pecking as an interaction between age and vegetation cover: in 2003 the presence of abundant vegetation decreased feather pecking in adults, whereas in 2004, on the contrary, this effect was observed only in chicks. A possible explanation for this effect could be the difference in the specific ages at which the birds were sampled in both years. In 2003 chicks were sampled earlier (42 days old) than in 2004 (67 days old). Thus, perhaps in 2003 chicks had not been exposed to the effect of vegetation enough time to reveal an impact on their behaviour reflected in the percentage of dorsum affected by feather pecking, which was only significant in adults. The fact that feather pecking in chicks sampled in 2004 was on average higher than in 2003 is consistent with this hypothesis (Table 4). On the other hand, in 2004 vegetation cover did not affect feather pecking in adults while it affected at the chick phase. We have no clear explanation for this differential pattern, and it seems that another environmental or internal uncontrolled factors can modulate the severity of feather pecking between years. In this sense, it is noteworthy that average densities in the aviaries were ca. 34 % higher in 2004 than in 2003 (Table 4), which would partly explain overall higher feather pecking levels, and maybe also the differential age by treatment dynamics. The overall differences in feather pecking levels among years could also be explained by variations in environmental factors. However, during the months of the experiment, the climatic conditions (see Supplementary Material, SM2) were similar in both years. Therefore, further research is needed to elucidate whether other factors may be affecting feather pecking behaviour and producing those interannual differences.

In any case, it is worth noting that this environmental enrichment approach alone was not sufficient to eliminate feather pecking in red-legged partridges, as birds have shown damaged areas during both years even in the presence of vegetation. Thus, future studies are necessary to investigate what other additional measures can be taken to contribute to the reduction of this stereotypy.

4.2. Weight and tarsus length

We only found partial evidence supporting our initial hypothesis that the presence of vegetation cover in outdoor aviaries would affect red-legged partridge morphometric parameters (i.e. weight and tarsus length). No effects on tarsus length were found in any of the study years. This may be due to the fact that this trait, which reflects skeletal size, is less plastic and relatively less sensitive to condition (Alatalo et al., 1990). Regarding weight, we found that during the 2004 trial, chicks inhabiting enclosures with abundant vegetation had marginally significantly higher body mass. This trend matches the above mentioned significant differences in feather pecking among chicks, as well as with the overall higher intensity of feather pecking in that year. This result therefore could suggest that vegetation coverage can play a relevant role in body mass gain in red-legged partridge chicks, buffering the impact of pecking behaviour on individual physiology. Chronic stress derived from environments with limited stimuli and opportunities to develop a normal behavioural repertoire can hamper body mass acquisition in young individuals, as glucocorticoid secretion shifts metabolic pathways, increasing catabolism to facilitate the mobilization of stored nutrients to cope with the stressor (Kitaysky et al., 2001; Kleiman et al., 2010; Favreau-Peigné et al., 2014; Blas, 2015). Moreover, the presence of abundant vegetation coverage may provide a higher availability and diversity of natural food resources such as invertebrates, which may enhance the diet of the birds (Silva-Monteiro et al., 2022). However, this effect was not significant during 2003 replicate, suggesting that it is a complex multifactorial phenomenon and that other uncontrolled factors could mask or nullify the effect.

One limitation of this study is that the sex of the birds could not be considered in the models because it was unknown. Birds were randomly assigned to the experimental groups and sex ratios should have been similar, and it is therefore unlikely that our findings are affected by any bias due to this. However, if the sex had been known, we could have explained a larger portion of the variance in models for weight and tarsus (traits that are sexually dimorphic in this species), and perhaps differences among vegetation treatments that might otherwise have remained unnoticed would have emerged.

Our study highlights the importance of including vegetation cover for body mass gain in red-legged partridge chicks, which can have noteworthy implications for both gamebird farming and the meat industry. Providing a more suitable environment with sufficient vegetation will not only contribute to the mitigation of feather pecking to comply with welfare conditions but may also aid in reaching an optimal weight for their release and to increased productivity in terms of chick weight gain. Moreover, our results point out that providing a more natural and suitable environment for captive red-legged partridges can reduce feather pecking, which could be important for their success after release. Both reaching an appropriate weight and ensuring plumage condition will be pivotal factors for surviving in the wild (Champagnon et al., 2012; Lamb et al., 2016; Jones et al., 2017). It is important to mention that we have evaluated the effect of feather-damaging behaviour in the dorsal part of the body, which can have thermoregulatory implications for their survival, but those feathers can regrow in a relatively short period of time. However, feather pecking can also affect tail, primary, and secondary feathers, so the damage would persist until the next molt, potentially affecting their flight capabilities, and consequently, their chances of survival in the wild. Future studies should also assess whether the environmental conditions in which partridges are raised can affect other relevant behaviours for their viability in their natural environment.

5. Conclusion

To our knowledge, this is the first study attempting to address and experimentally test management measures to mitigate feather pecking behaviour in captive red-legged partridges housed in outdoor aviaries. Including vegetation cover has been proven to be successful in reducing feather pecking, and we found limited evidence during one year that can improve the body condition of the chicks. However, future studies are needed to find additional measures to reduce feather pecking, as this abnormal behaviour was still present in the groups inhabiting enclosures with abundant vegetation.

On the other hand, it is also important to stress that there were statistically significant differences between individuals during the 2004 trial, which means that feather pecking might be also modulated by differences between individuals influenced by personality and genetics (Rodenburg et al., 2004; 2010; Wysocki et al., 2010; Kops et al., 2013; Pichová et al., 2021). For example, it has been reported that feather pecking is a heritable trait in hens, as certain breed lines are more prone to display this behaviour (Wysocki et al., 2010). Future studies would be needed to investigate which genetic and personality traits, as well as housing densities, that may be linked to feather pecking in red-legged partridges.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2024.106457.

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