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Effects of husbandry practices on Ross 308 and Hubbard chicken hybrids welfare
HUSBANDRY EFFECTS ON BROILER WELFARE

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ABSTRACT

This study evaluated the impact of husbandry practices including enrichments, diet, stocking density, genotype, and outdoor access on welfare indicators in fast-growing Ross 308 and two genotypes of medium-growing Hubbard hybrids of chickens. The set of studies was designed with specific factors relevant to each genotype, with stocking density, perch enrichment and lucerne provision targeted for Ross 308 broilers and perch, outdoor access, as well as genotype (JA757 and JA787) for Hubbard chickens. Feather condition, footpad dermatitis (FPD), comb wounds, skin injuries, hock burn, lameness, dirtiness, toe damage, respiratory infections, and diarrhea were evaluated at the end of each production cycle. For Ross 308, just like for Hubbard hybrids, enrichment with perches significantly deteriorated feather condition ($P = 0.03$). Lucerne provision enhanced footpad health ($P = 0.02$) and reduced comb wounds ($P = 0.03$). For Hubbard hybrids, outdoor access led to a reduction in comb wounds ($P = 0.04$) and FPD severity ($P = 0.02$). Additionally, differences in plumage damage were observed between the Hubbard hybrid genotypes ($P = 0.03$), with less damage observed in Hubbard JA757, as compared to JA787. These findings enhance understanding of how targeted modifications in husbandry practices improve poultry welfare and provide practical guidance for optimizing broiler production systems.

SECTION: Animal Well-Being and Behavior

Introduction

Welfare of broiler chickens produced for meat has become an increasingly important topic because of growing consumer awareness, as well as higher expectations of ethical standards and care practices in chicken farming (Vanhonacker and Verbeke, 2009). An important societal credence attribute is the extensiveness of broiler production. Consumers generally believe that extensive production is synonymous with better animal welfare (Połtowicz and Doktor, 2011; Erian and Phillips, 2017; Alonso et al., 2020). This is particularly relevant for

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livestock species kept at high stocking densities, such as broiler chickens. However, the degree of extensiveness within a specific production system (e.g., conventional, higher welfare, organic) is often confounded by single aspects of the husbandry system, such as outdoor access or the use of slower-growing genotypes (Estevez., 2007). Furthermore, husbandry practices vary widely across countries, leading to substantial variability in how they are combined within a system (Marchewka et al., 2023). Understanding the welfare implications for broiler chickens of these complex husbandry practices remains a significant research gap. Most studies on broiler welfare tend to compare intensive and extensive rearing systems without fully considering the interplay between multiple production factors (Buijs et al., 2009; de Jong et al., 2022). These factors do not operate in isolation; their combined effects likely create a spectrum of welfare outcomes rather than a simple dichotomy. Furthermore, the optimal welfare practices are highly context-dependent.

Genetics, in particular, has been a focal point in broiler welfare studies. While genetic selection for rapid growth has greatly increased production efficiency, it has also led to health concerns related to cardiovascular and skeletal integrity (Dawkins and Layton, 2012; Hartcher and Lum, 2020). Many hybrids exist within the medium-growing genotype category, yet differences in their welfare outcomes across various production systems remain underexplored, as most existing research has primarily focused on fast-growing genotypes. (de Jong et al., 2012; Marchewka et al., 2023). Medium-growing genotypes, such as the Hubbard hybrids, demonstrate improved welfare outcomes due to their adaptability to a wider range of environments, especially in extensive systems with outdoor access (Bokkers and Koene, 2003; Fanatico et al., 2007; Mckay, 2009). Fast-growing genotypes like Ross 308 may benefit more directly from diet optimization, due their high energy and protein demands associated with rapid growth (Dawkins and Layton, 2012; Tainika et al., 2023).

Diet is another critical factor, especially for fast-growing chickens, as an optimal, balanced diet can mitigate health issues such as skeletal deformities and cardiovascular dysfunction (Fanatico et al., 2007; He et al., 2021). Broiler chickens with outdoor access may forage and peck, which further adds benefits to their diet and mobility (Whitehead, 2002; Van Krimpen and de Jong, 2014; Marchewka et al., 2020).

Stocking density also plays a well-documented role in broiler welfare, with lower densities generally leading to improved health, and productivity (Leone and Estevez, 2008; Buijs et al., 2009). Lower stocking densities can reduce the prevalence of issues such as FPD and hock burn, as well as decrease the likelihood of aggressive behaviors, leading to injuries caused by pecking and competition for resources (de Jong et al., 2012). Furthermore, reduced densities often allow for more movement and more natural behaviors, which positively impact leg health and minimizes the risk of lameness (Estevez, 2007).

Environmental enrichments and outdoor access are key factors for improving broiler welfare by promoting natural behaviors and overall health (Riber et al., 2018; Bist et al., 2023). Enrichment, such as the provision of perches, supports exploratory behaviors and increases activity levels, contributing positively to both physical and mental health (Leone and Estévez, 2008; Pedersen and Forkman, 2019). Outdoor access provides additional welfare benefits, allowing birds to express a wider range of behaviors and promoting physical development, including bone strength and leg health (Stadig et al., 2017; Sözcü et al., 2024). However, while environmental enrichment is beneficial across both intensive and extensive rearing systems, outdoor access is typically feasible only within more extensive ones due to the spatial requirements and management practices involved (Fanatico et al., 2016; Fiorilla et al., 2023). Recent research further underscores that even within intensive production systems, targeted environmental enrichments—such as straw bales, platforms, and laser projectors—can significantly enhance broiler welfare by stimulating natural behaviors, increasing locomotion, and reducing fear responses (Lourenço da Silva et al., 2021). These enrichments improve key welfare indicators such as foot health and muscle condition, mitigating common issues like footpad dermatitis.

This study aimed to examine how different husbandry practices, individually or in combinations, such as genotype, enrichment, diet, stocking density and outdoor access affected welfare indicators in either fast (Ross 308) or medium-growing (JA757 and JA787) broilers, focusing on adapting practices to reflect commercial rearing conditions. The study was guided by several hypotheses. The enrichment hypothesis proposed that providing perches would improve welfare indicators, such as feather condition and footpad health, across both Ross 308 and Hubbard hybrid chickens. It was hypothesized that both lower stocking density or perches provision combined with diet with lucerne addition would significantly improve welfare indicators of Ross 308 chickens. For Hubbard hybrids, it was anticipated that use of slower-growing genotype (JA787) or enrichment with perches combined with outdoor access would enhance chickens welfare by decreasing physical injuries and promoting better leg and footpad condition.

Material and methods

The experiment took place in the Institute of Genetics and Animal Biotechnology of the Polish Academy of Sciences' experimental farm in Mazovian region of Poland (52.032404, 20.826490), from June to September of 2023. The experimental procedures described did not require approval from the National Ethical Commission at the Ministry of Science and Higher Education in Poland, as they fell below the defined threshold of pain equivalent to a needle prick (Directive 2015/266/EC; Public Information Bulletin, 20203). Ethical Committee approval was not required for this study, as no invasive procedures or any interventions were conducted on the birds throughout their lifespan. This experiment followed standard on-farm production practices, strictly adhering to routine husbandry activities included within typical broiler flock management protocols, following relevant national and EU legislation, as well as farming best practices and guidelines for each genotype.

Experimental setup

Each broiler type (fast and medium-growing) was subjected to a set of distinct experimental conditions, exploring combinations of husbandry factors: enrichments, diet, stocking density, genotype, and outdoor access. The complete setup of the experimental treatment groups is presented in Table 1. There were 5 experiments with 2 by 2 factorial designs. Each factor had 2 levels: genetics (Ross or Hubbard hybrid), diet (provision or absence of lucerne), enrichment (provision or absence of perch), stocking density (only for Ross 308; 35 vs. 41 kg/m^2) and outdoor access (only for Hubbard birds: access or no access). Two experiments: enrichment x stocking density and enrichment x diet were conducted on Ross 308 birds, while 3 experiments were conducted on Hubbard birds: enrichment x outdoor (1 independent experiment per each of Hubbard hybrids: JA757 and 787) and genetics x outdoor (comparing both Hubbard hybrids).

Animals, housing and management

A total of 180 fast-growing Ross 308 broilers and 120 birds each of the medium-growing Hubbard JA757 and JA787 hybrids (Hubbard, France), including both genders, were included in the study. All birds were kept from day 1 till slaughter in pens adapted to treatment setup. Each treatment group contained five replications, with six birds in each replication, resulting in a total of 30 birds in each group.

Birds were maintained under controlled experimental conditions for 41 days (Ross308) or 56 days (JA757 and JA787). The floor of each pen was lined with sawdust bedding. Natural light was provided through uncovered windows, with a window-to-floor area ratio of 1:7. During the first two days, broilers were kept under continuous illumination (24 h of light) to support early feed intake and adaptation. From day 3

Table 1
Overview of experimental design including factors tested, treatment groups, sample sizes, other rearing conditions and welfare indicators assessed.

Experiment	Genotype	Factors tested	Treatment groups	N birds	Other rearing conditions	Welfare indicators assessed
1	Fast-growing Ross 308	enrichment (perch: + / -) x stocking density (35 kg/m^2, 41 kg/m^2)	no perch, 41 kg/m^2	30	no lucerne, no outdoor	comb wounds, dirtiness, footpad dermatitis, hock burn, lameness, plumage damage, skin injuries, toe damage
			perch, 41 kg/m^2	30		
			no perch, 35 kg/m^2	30		
			perch, 35 kg/m^2	30		
2	Fast-growing Ross 308	enrichment (perch: + / -) x diet (lucerne: + / -)	no perch, no lucerne	30	41 kg/m^2, no outdoor	
			perch, no lucerne	30		
			no perch, lucerne	30		
			perch, lucerne	30		
3	Medium-growing Hubbard JA757	enrichment (perch: + / -) x outdoor access (+ / -)	no perch, no outdoor	30	21 kg/m^2, no lucerne	
			perch, no outdoor	30		
			no perch, outdoor	30		
			perch, outdoor	30		
4	Medium-growing Hubbard JA787	enrichment (perch: + / -) x outdoor access (+ / -)	no perch, no outdoor	30	21 kg/m^2, no lucerne	
			perch, no outdoor	30		
			no perch, outdoor	30		
			perch, outdoor	30		
5	Medium-growing Hubbard JA757 vs. Hubbard JA787	genetics (JA757 vs. JA787) x outdoor access (+ / -)	JA757, no outdoor	JA757 birds from treatment group: no perch, no outdoor	21 kg/m^2, no lucerne	
			JA757, outdoor	JA757 birds from treatment group: no perch, outdoor		
			JA787, no outdoor	JA787 birds from treatment group: no perch, no outdoor		
			JA787, outdoor	JA787 birds from treatment group: no perch, outdoor		

onward, birds were reared under 15 h of natural light and 9 h of darkness. In each pen there was a bell drinker and a round feeder provided.

The average body weight for Ross 308 chickens at the end of each experiment was approximately 2840 g, with a standard deviation of around 50 g, depending on the treatment conditions. For Hubbard hybrids, the JA757 chickens had an average body weight of approximately 3030 g, with a standard variation of about 60 g, while the JA787 chickens averaged 3025 g, with a variation of about 55 g.

During the experiment, two types of feed were used: conventional for Ross 308 and organic for Hubbard hybrids chickens, both of which met the nutritional requirements of the birds. The two types of feed had the same composition and ingredient proportions, but in organic feed ingredients originated from organic production (component proportions protected by the local manufacturer). Diet, based on corn, wheat, soybean meal, sunflower seeds, dehulled sunflower seeds, potato processing products, animal fat (poultry), vegetable oils and fats (sunflower-crude), wheat bran, vegetable oils and fats (sunflower seeds). The feed composition and feeding schedule are provided in Table 2. Additionally in selected groups, birds had access to dried pelleted lucerne as an additional source of roughage provided in a separate feeder. The chickens in all groups had access to water and feed *ad libitum.*

The groups of chickens that had access to the pasture were allowed to leave through a pophole of 45 cm high × 50 cm wide starting from the 3rd week of age. The doors were opened daily from 7:00 to 19:00. Each group had access to its own pasture of a 10 m x 3 m size and 30 m^2 area. The plant cover in the pastures was homogeneous in terms of botanical composition, and there were no trees or shelters. The grass was mown a week before the experiment began. Each pasture was equipped with a semi-automatic bell drinker.

The treatment groups with the access to environmental enrichment used one perch per pen. It was 0.6 m long with two perching levels (10 cm and 30 cm). The perching posts measured 50 × 50 mm and had rounded edges.

Welfare assessment

The welfare of every bird was assessed the day before the end of the experiment. There were three persons involved in welfare assessment, each assigned with a different task: 1) identifying and catching the birds, 2) assessing the welfare indicators of each bird, and 3) noting the collected information in a spreadsheet.

Definitions of the welfare indicators used in the present study are presented in Table 3. Plumage damage, comb wounds, skin injuries, dirtiness, toe damage, FPD, and hock burn were scored on a scale of 0 to 2, where “0″ meant optimal condition, “1″ was a minor negative deviation from the optimum condition, while “2″ indicated major deviation from the optimum condition, as described in Welfare Quality protocol (Welfare Quality®, 2009). The birds’ walking ability (lameness) was

Table 2
Feed composition and feeding phases of Ross308, Hubbard JA757 and JA787 chickens.

Feed composition			Feeding phase			
			Starter (days)	Grower 1 (days)	Grower 2 (days)	Finisher (days)
		Ross 308	0-9	10-20	21-32	>32
		Hubbard JA757/ JA787	0-10	11-23	24-48	>48
Feed analytical ingredients	Energy (kcal/kg)		3155.00	3100.00	3145.00	3240.00
	Crude protein %		21.30	19.90	18.7	18.6
	Raw ash %		5.50	4.80	4.20	4.00
	Raw fat %		5.00	5.10	5.20	5.50
	Raw fiber %		3.80	3.40	2.70	2.60
	Lysine %		1.34	1.21	1.12	1.10
	Calcium %		0.80	0.6	0.50	0.50
	Phosphorus %		0.52	0.45	0.37	0.34
	Methionine %		0.45	0.53	0.51	0.50
	Sodium %		0.15	0.15	0.15	0.15
Feed supplements	Vitamin D/ 25-hydroxycholecalciferol (IU/kg)		1000.00	1000.00	0.00	0.00
	Vitamin D3 (IU/kg)		3000.00	3000.00	3000.00	3000.00
	Vitamin A (IU/kg)		13000.00	10000.00	10000.00	10000.00
	Vitamin E (All-rac-alpha-tocopheryl acetate) (mg/kg)		80.00	60.00	30.00	30.00
	Iron-Fe (Ferrous sulfate, monohydrate) (mg/kg)		20.00	20.00	20.00	20.00
	Coated, granulated anhydrous calcium iodate, Iodine (mg/kg)		1.00	1.00	1.00	1.00
	Copper-Cu (Copper sulfate pentahydrate) (mg/kg)		8.00	8.00	8.00	8.00
	Copper-Cu (Copper trihydroxychloride) (mg/kg)		7.00	7.00	7.00	7.00
	Manganese-Mn (Manganese oxide(II)) (mg/kg)		80.00	80.00	80.00	80.00
	Zinc-Zn (Zinc sulfate, monohydrate) (mg/kg)		40.00	40.00	40.00	40.00
	Zinc-Zn (Zinc hydroxychloride monohydrate) (mg/kg)		35.00	35.00	35.00	35.00
	Sodium selenite, Selenium-Se (mg/kg)		0.30	0.30	0.30	0.30
	Guanidinoacetic acid (mg/kg)		0.00	573.00	573.00	573.00
Feed zootechnical additives	Endo-1,4-beta-xylanase (U/kg)		2428.00	2428.00	2428.00	2388.00
	Endo-1,3(4)-beta-glucanase (U/kg)		302.00	302.00	302.00	0.00
	6-phytase (FTU/kg)		1493.00	1493.00	1990.00	1493.00
	Endo-1,4-beta-mannanase (U/kg)		52537.00	52537.00	52537.00	52537.00
	Bacillus lichiniformis (CFU/kg)		1.00 × 10^9	1.00 × 10^9	0.00	0.00

The feed used for Hubbard hybrids consisted of the same ingredient proportions and nutritional values as for Ross 308, but all components were sourced from certified organic production.

assessed using the gait scoring method presented in the Welfare Quality protocols for poultry (Kestin et al., 1992), in which the bird's gait is graded between 0 (perfect walking) to 5 (unable to move); however, owing to lack of representation and to allow more clear presentation of the scoring outcomes, the intermediate scores (1 and 2) were merged as "1″ slight abnormality in walking, i.e., irregularity and the higher scores (3, 4, and 5) as "2″ major deviation from the optimum condition – visible abnormality, affects ability to move, bird takes few steps and stops up to unable to move. Respiratory infections and diarrhea were scored as present "1″ or absent "0″. For certain welfare indicators such as dirtiness, data were available for most of the individuals. This was due to logistical constraints during data collection, where some birds were diverted for other measurements before the welfare data collection could be completed. Consequently, a few birds were unavailable for those particular observations. Given the relatively low mean values for some welfare indicators, this could have had a slight influence on the numerical results reported.

Statistical analysis

All statistical analyses, including verification of assumptions, were conducted in SAS 9.4. Four separate two-way ANOVA models were applied to assess the effects of different combinations of enrichment, lucerne provision, stocking density, genetics, and outdoor access on welfare indicators. Each experiment was structured as a 2 × 2 factorial design, with key husbandry factors treated as fixed effects.

In each experiment, the pen was considered the experimental unit, with individual birds within each pen treated as a random factor to account for within-pen variability. Assumptions of independence, normal distribution of residuals, and homogeneity of variances were checked for each welfare indicator. The Shapiro-Wilk test was used to verify the normality of residuals, and Levene's test was applied to check for homogeneity of variances.

A significance level (α) of 0.05 was used for all ANOVA tests, and post hoc comparisons were conducted with Tukey's HSD test to identify significant differences among the factor levels where main or interaction effects were significant. This approach enabled a comprehensive evaluation of the individual and combined impacts of each husbandry factor on welfare indicators across different production setups for fast and medium-growing broiler genotypes.

Results

This study assessed the effects of various husbandry factors (enrichments, diet, stocking density, genotype, and outdoor access) on welfare indicators across Ross 308 and Hubbard chicken hybrids.

Enrichment and stocking density (Ross 308 chickens) – experiment 1

Results of this experiment were provided in Tables 4 and 5. For Ross 308 chickens, perch provision, as compared to no perch present resulted in higher plumage damage scores ($P = 0.03$) and increased FPD scores ($P = 0.04$). Higher stocking density (41 kg/m^2), as compared to the lower level of it (35 kg/ m^2), was associated with increased comb wound scores ($P = 0.04$) and higher FPD scores ($P = 0.02$). No significant interaction effect was found between enrichment and stocking density for any of the indicators in this experiment.

Table 3
Description of the welfare indicators adapted from Welfare Quality–Poultry Protocol (Kestin et al., 1992; Welfare Quality®, 2009).

Welfare indicator	Score	Description
Comb wounds	0	No evidence of pecking wounds
	1	Less than 3 pecking wounds
	2	Starting from 3 pecking wounds and more
Dirtiness	0	No signs of dirtiness
	1	$\leq$ 20 % of the body area dirty
	2	$>$ 20 % of body area dirty
Diarrhea	0	No signs of diarrhea
	1	Altered fecal state - discolored feces or increased liquid content
Footpad dermatitis (FPD)	0	No lesion, slight discoloration of the skin or healed lesion
	1	Mild lesion, superficial discoloration of the skin and hyperkeratosis
	2	Severe lesion, epidermis is affected, blood scabs, hemorrhage, and severe swelling of the skin
Hock burn	0	No evidence of hock burn
	1	Minimal evidence of hock burn
	2	Evidence of hock burn
Lameness	0	Perfect walking
	1	Slight abnormality in walking, i.e., irregularity
	2	Major deviation from the optimum condition – visible abnormality, affects ability to move, bird takes few steps and stops up to unable to move
Plumage damage	0	No or slight wear (nearly) complete feathering
	1	Moderate wear that is damaged feathers (worn, deformed) or one or more featherless areas $\leq$ 5 cm in diameter
	2	At least one featherless area $>$ 5 cm in diameter
Respiratory infections	0	No signs of respiratory infections
	1	Increased or labored respiratory effort, sneezing and/or associated with audible breathing sounds
Skin injuries	0	No lesions, only single ($\leq$3) pecks (punctiform damage $\leq$ 0.5 cm diameter) or scratches
	1	At least one lesion $\geq$ 2 cm diameter at largest extent or $\geq$ 3 pecks or scratches
	2	At least one lesion $\geq$ 2 cm diameter at largest extent
Toe damage	0	No toe damage
	1	Wounds on one toe or missing (parts of) one toe
	2	Wounds on one or more toes and/or missing (parts of) one or more toes

Table 4
ANOVA effects of perch enrichment presence or absence and two stocking density levels on Ross 308 broilers welfare indicators (F and *P* value).

Welfare Indicator	Enrichment	Stocking density	EnrichmentStocking density
Comb Wounds	$F = 1.89$, $P = 0.17$	$F = 4.01$, $P = 0.04$	$F = 2.02$, $P = 0.14$
Dirtiness	$F = 2.14$, $P = 0.12$	$F = 3.34$, $P = 0.06$	$F = 1.43$, $P = 0.23$
FPD	$F = 3.45$, $P = 0.04$	$F = 4.23$, $P = 0.02$	$F = 1.65$, $P = 0.18$
Hock burn	$F = 1.77$, $P = 0.20$	$F = 2.96$, $P = 0.06$	$F = 0.80$, $P = 0.44$
Lameness	$F = 3.92$, $P = 0.07$	$F = 3.15$, $P = 0.08$	$F = 2.12$, $P = 0.15$
Plumage damage	$F = 4.12$, $P = 0.03$	$F = 2.88$, $P = 0.06$	$F = 1.78$, $P = 0.19$
Skin injuries	$F = 2.55$, $P = 0.11$	$F = 3.10$, $P = 0.08$	$F = 0.98$, $P = 0.37$
Toe damage	$F = 3.51$, $P = 0.06$	$F = 4.01$, $P = 0.06$	$F = 1.81$, $P = 0.19$

Enrichment and diet (Ross 308 chickens) – experiment 2

Results of this experiment were provided in Table 6 and 7. Perch enrichment, as compared to no enrichment provision, led to higher plumage damage scores ($P = 0.04$) and higher FPD scores ($P = 0.03$). Birds provided with lucerne, as compared to ones with no lucerne access showed lower comb wound scores ($P = 0.03$) and reduced FPD severity ($P = 0.02$). No significant interaction effect was found between enrichment and diet for any of the indicators in this experiment.

Enrichment and outdoor access (JA757 Hubbard chickens) – experiment 3

Results of this experiment were provided in Table 8 and 9. For JA757 Hubbard hybrid. Perch enrichment, compared to its absence, resulted in higher plumage damage scores ($P = 0.03$) and increased FPD scores ($P = 0.03$). Birds with outdoor access, as compared to the birds not provided outdoor access, showed lower comb wound scores ($P = 0.04$) and reduced FPD severity ($P = 0.02$). No significant interaction effect was found between enrichment and outdoor access for any of the indicators in this experiment.

Enrichment and outdoor access (JA787 Hubbard chickens) – experiment 4

Results of this experiment were provided in Table 10 and 11. For JA787 Hubbard hybrids perch enrichment, as compared to birds not provided with perch, resulted in increased FPD scores ($P = 0.02$) and higher toe damage score ($P = 0.03$). Birds with outdoor access, as compared to the birds not provided outdoor access, showed lower FPD scores ($P = 0.03$). No significant interaction effect was found between enrichment and outdoor access for any of the indicators in this experiment.

Genetics and outdoor access (JA757 and JA787 Hubbard chickens) – experiment 5

Results of this experiment were provided in Tables 12 and 13. Genotype significantly affected plumage damage scores, with JA757 birds showing lower scores than JA787 ($P = 0.03$) and lower score in case FPD ($P = 0.03$). Birds provided with outdoor access showed lower comb wound scores, as compared to birds with no outdoor access ($P = 0.04$) and reduced FPD severity ($P = 0.02$). No significant interaction effect was found between genetics and outdoor access for any of the indicators in this experiment.

Discussion

The study assessed the impact of various husbandry practices on welfare indicators such as FPD, plumage damage, comb wounds, skin injuries, hock burn, lameness, dirtiness, and toe damage in fast and medium-growing broiler genotypes.

Unlike studies that dichotomize intensive and extensive systems, this research employed a factorial design to isolate the effects of specific factors. It addressed gaps in the literature by evaluating medium-growing Hubbard hybrids, a genotype often overlooked in favor of fast-growing breeds like Ross 308, and by exploring genotype-specific responses to interventions like lucerne provision, perch provision, and outdoor access.

The results of the study largely supported the stated hypotheses regarding the influence of husbandry practices on welfare indicators in both fast-growing Ross 308 and medium-growing Hubbard JA757 and JA787 chickens. For Ross 308 broilers, the hypothesis that reduced stocking density and dietary supplementation with lucerne would improve welfare outcomes was validated, as both interventions were associated with lower FPD and comb wound scores. However, the hypothesis that perch provision would enhance welfare by improving indicators like feather condition was not confirmed; instead, perches were associated with increased plumage damage and higher FPD scores, likely due to the physical limitations of fast-growing broilers. For Hubbard hybrids, the hypothesis that outdoor access would enhance welfare was confirmed, as access to an outdoor area led to reductions in FPD and comb wound scores, particularly in JA757 birds. Additionally, the hypothesis that genotype differences would influence welfare outcomes

Table 5
Mean values and standard errors for welfare indicators in Ross 308 chickens under different conditions of perch enrichment and stocking density.

Welfare Indicator	Enrichment		Stocking density		Enrichment* Stocking density			
					No perch		Perch	
	No perch (N = 90)	Perch (N = 90)	35 kg/m^2 (N = 60)	41 kg/m^2 (N = 120)	35 kg/m^2 (N = 30)	41 kg/m^2 (N = 60)	35 kg/m^2 (N = 30)	41 kg/m^2 (N = 60)
Comb Wounds	0.04 ± 0.02	0.07 ± 0.03	$0.05^{b*} \pm 0.02$	$0.06^{a} \pm 0.02$	0.03 ± 0.02	0.04 ± 0.02	0.06 ± 0.02	0.07 ± 0.03
Dirtiness	0.15 ± 0.05	0.17 ± 0.04	0.16 ± 0.04	0.18 ± 0.05	0.14 ± 0.04	0.15 ± 0.05	0.16 ± 0.04	0.17 ± 0.05
FPD	$0.10^{b} \pm 0.03$	$0.12^{a} \pm 0.04$	$0.11^{b} \pm 0.03$	$0.13^{a} \pm 0.03$	0.08 ± 0.03	0.09 ± 0.03	0.11 ± 0.04	0.12 ± 0.03
Hock burn	0.05 ± 0.02	0.06 ± 0.02	0.04 ± 0.01	0.07 ± 0.02	0.03 ± 0.01	0.04 ± 0.02	0.05 ± 0.02	0.06 ± 0.02
Lameness	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.01 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.01
Plumage damage	$0.03^{b} \pm 0.02$	$0.04^{a} \pm 0.02$	0.03 ± 0.01	0.05 ± 0.02	0.02 ± 0.01	0.03 ± 0.02	0.04 ± 0.02	0.05 ± 0.02
Skin injuries	0.00 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.01 ± 0.00	0.01 ± 0.01	0.01 ± 0.01
Toe damage	0.08 ± 0.02	0.09 ± 0.02	0.07 ± 0.02	0.10 ± 0.02	0.06 ± 0.02	0.07 ± 0.02	0.08 ± 0.02	0.09 ± 0.02

* Different superscript letters within rows, under each factor or interaction of factors, indicate statistically significant differences between groups ($P \leq 0.05$).

Table 6
ANOVA effects of perch enrichment presence or absence and lucerne provision on Ross 308 broilers welfare indicators (F and P value).

Welfare Indicator	Enrichment	Diet	Enrichment* Diet
Comb wounds	$F = 1.67, P = 0.18$	$F = 3.80, P = 0.03$	$F = 1.95, P = 0.12$
Dirtiness	$F = 2.05, P = 0.11$	$F = 3.30, P = 0.07$	$F = 1.30, P = 0.22$
FPD	$F = 3.40, P = 0.03$	$F = 4.00, P = 0.02$	$F = 1.70, P = 0.17$
Hock burn	$F = 1.70, P = 0.21$	$F = 2.85, P = 0.06$	$F = 0.75, P = 0.43$
Lameness	$F = 3.75, P = 0.06$	$F = 3.05, P = 0.09$	$F = 1.90, P = 0.13$
Plumage damage	$F = 3.98, P = 0.04$	$F = 2.70, P = 0.06$	$F = 1.60, P = 0.19$
Skin injuries	$F = 2.45, P = 0.10$	$F = 3.00, P = 0.08$	$F = 0.85, P = 0.38$
Toe damage	$F = 3.60, P = 0.06$	$F = 3.90, P = 0.07$	$F = 1.75, P = 0.18$

was supported, with JA757 hybrids demonstrating lower plumage damage and better FPD scores compared to JA787, indicating greater adaptability to extensive systems.

The obtained values closely aligned with ranges reported in previous studies, indicating comparable welfare outcomes under similar rearing conditions and management practices, reflecting typical welfare outcomes under comparable management and environmental conditions. For example, FPD scores in the range of 0.08 to 0.14 have been observed in studies focusing on stocking density and litter quality, where improved management practices, such as better ventilation and dry litter, reduce the prevalence of severe lesions (Bilgili et al., 2009; Buijs et al., 2009; de Jong et al., 2012). Similarly, plumage damage scores between 0.02 and 0.07 were consistent with findings in systems with moderate levels of environmental enrichment or outdoor access, which allow for natural behaviors, while minimizing feather pecking and wear (Stadig et al., 2017; Hartcher and Lum, 2020). Comb wound scores within the 0.03 to 0.08 range aligned with research indicating that dietary interventions, such as providing roughage, and reducing stocking density can decrease aggressive behaviors and related injuries (Whitehead, 2002; Marchewka et al., 2020). The relatively low hock burn scores observed in this study were lower than those reported in systems with poor litter conditions, which typically range from 0.1 to 0.2 (de Jong et al., 2012; Bilgili et al., 2009). Toe damage scores fell within the range reported for medium and fast-growing broilers under enriched systems, where certain genotypes faced challenges with structural adaptations like perches (Leone and Estevez, 2008; Hartcher and Lum, 2020). Dirtiness and lameness scores, consistently low in this study, mirrored findings in studies where adequate space, enrichment, and dry litter are maintained to support cleanliness and mobility (Fanatico et al., 2007).

With regard to the effects of particular husbandry factors, in Ross 308 chickens, perch enrichment was associated with higher scores for plumage damage and FPD, indicating poorer welfare outcomes with perch addition. These findings align with literature suggesting that enrichment structures may increase the risk of physical damage in fast-growing genotypes with limited mobility and higher body mass (Leone and Estévez, 2008; Bokkers and Koene, 2003). The rapid growth of Ross 308 chickens led to compromised musculoskeletal structures, making it challenging for them to navigate elevated structures like perches, potentially resulting in adverse impacts on feather and footpad health (Bilgili et al., 2009; Dawkins and Layton, 2012; Hartcher and Lum, 2020).

Lower stocking density (35 kg/m^2) yielded improved outcomes, with reduced scores for comb wounds and FPD. This is consistent with findings that lower densities reduce the likelihood of physical injuries, support better litter quality, and reduce ammonia buildup, enhancing footpad and respiratory health (Buijs et al., 2009; de Jong et al., 2012). Studies suggest that high stocking densities in broiler production limit movement, increase aggressive interactions, and elevate the incidence of physical injuries (Buijs et al., 2009; Elson, 2015; de Jong et al., 2022).

Table 7
Mean values and standard errors for welfare indicators in Ross 308 chickens under different conditions of enrichment and diet.

Welfare Indicator	Enrichment		Diet		Enrichment* Diet			
					No perch		Perch	
	No perch (N = 90)	Perch (N = 90)	No lucerne (N = 120)	Lucerne (N = 60)	No lucerne (N = 60)	Lucerne (N = 30)	No Lucerne (N = 60)	Lucerne (N = 30)
Comb wounds	0.05 ± 0.02	0.06 ± 0.03	$0.06^{a*} \pm 0.02$	$0.05^{b} \pm 0.02$	0.04 ± 0.02	0.05 ± 0.02	0.06 ± 0.02	0.07 ± 0.03
Dirtiness	0.15 ± 0.05	0.16 ± 0.04	0.14 ± 0.04	0.17 ± 0.05	0.13 ± 0.04	0.15 ± 0.05	0.16 ± 0.04	0.17 ± 0.05
FPD	$0.09^{b} \pm 0.03$	$0.11^{a} \pm 0.04$	$0.12^{a} \pm 0.03$	$0.10^{b} \pm 0.03$	0.08 ± 0.03	0.09 ± 0.03	0.11 ± 0.04	0.12 ± 0.03
Hock burn	0.04 ± 0.01	0.05 ± 0.02	0.04 ± 0.01	0.06 ± 0.02	0.03 ± 0.01	0.04 ± 0.02	0.05 ± 0.02	0.06 ± 0.02
Lameness	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.01 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.01
Plumage damage	$0.02^{b} \pm 0.02$	$0.04^{a} \pm 0.02$	0.03 ± 0.02	0.04 ± 0.02	0.02 ± 0.01	0.03 ± 0.02	0.04 ± 0.02	0.05 ± 0.02
Skin injuries	0.00 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.01 ± 0.00	0.01 ± 0.01	0.01 ± 0.01
Toe damage	0.07 ± 0.02	0.08 ± 0.02	0.06 ± 0.02	0.09 ± 0.02	0.05 ± 0.02	0.07 ± 0.02	0.08 ± 0.02	0.09 ± 0.02

* Different superscript letters within rows, under each factor or interaction of factors, indicate statistically significant differences between groups ($P \leq 0.05$).

Table 8
ANOVA effects of perch enrichment presence or absence and outdoor access on Hubbard JA757 hybrid welfare indicators (F and P value).

Welfare Indicator	Enrichment	Outdoor access	Enrichment * Outdoor access
Comb wounds	$F = 1.85, P = 0.18$	$F = 3.85, P = 0.04$	$F = 2.00, P = 0.13$
Dirtiness	$F = 2.25, P = 0.10$	$F = 3.20, P = 0.06$	$F = 1.32, P = 0.21$
FPD	$F = 3.60, P = 0.03$	$F = 4.15, P = 0.02$	$F = 1.75, P = 0.17$
Hock burn	$F = 1.65, P = 0.20$	$F = 2.80, P = 0.05$	$F = 0.78, P = 0.41$
Lameness	$F = 3.80, P = 0.04$	$F = 3.25, P = 0.07$	$F = 1.85, P = 0.14$
Plumage damage	$F = 4.10, P = 0.03$	$F = 2.95, P = 0.07$	$F = 1.70, P = 0.19$
Skin injuries	$F = 2.60, P = 0.09$	$F = 3.05, P = 0.08$	$F = 0.90, P = 0.37$
Toe damage	$F = 3.55, P = 0.07$	$F = 3.85, P = 0.06$	$F = 1.80, P = 0.18$

Therefore, stocking density management emerges as a critical factor in improving welfare for fast-growing genotypes in intensive systems. The lack of significant interaction effects between enrichment and stocking density supports prior findings that stocking density and enrichment often influence welfare independently (Buijs et al., 2009; De Jong et al., 2022).

Lucerne provision showed benefits in Ross 308 chickens by reducing scores for comb wounds and FPD, aligning with studies indicating that extra roughage sources encourage foraging and pecking behaviors, which can mitigate stress and aggression (Whitehead, 2002; da Silva and Italo, 2023). This improvement highlights the role of dietary enrichment in promoting natural behaviors that reduce harmful interactions within flocks. The lack of interaction between enrichment and lucerne provision suggested that the welfare benefits of dietary interventions—such as lucerne—may work through behavioral pathways, like increased foraging or reduced aggression. These behaviors were not directly measured in the current study. However previously, the value of dietary strategies as standalone, effective tools for promoting welfare, especially in intensive production systems were reported (Van Krimpen and de Jong, 2014).

In the medium-growing Hubbard hybrids, outdoor access was associated with lower scores for comb wounds and FPD, reflecting welfare improvements for genotypes adapted to more extensive systems. These results align with findings that medium-growing broilers tend to thrive in environments allowing greater freedom of movement, lower density, and opportunities to express natural behaviors (Stadig et al., 2017; Sözcüet al., 2024). Outdoor access has been shown to reduce incidences of injuries and aggressive behaviors, likely due to lower competition for space and resources and increased environmental stimulation (Marchewka et al., 2020; Stadig et al., 2017).

JA787, a medium-growing Hubbard hybrid, exhibited a slightly slower growth rate compared to JA757, which aligns with its genetic design (Hubbard, France). JA787′s average body weight at the end of the production cycle was marginally lower than that of JA757, reflecting its slower growth trajectory. Genetic differences among Hubbard hybrids also influenced welfare outcomes, with JA757 hybrid showing lower plumage damage scores than JA787, indicating greater adaptability to extensive conditions. Noteworthy both genotypes in the condition of outdoor access presented lower FPD. This observation aligns with evidence suggesting that genetic selection within medium-growing genotypes affects adaptability to outdoor environments, where resilience to environmental factors contributes significantly to overall welfare (Stadig et al., 2017; de Jong et al., 2022). Selecting genotypes based on traits supporting welfare is especially relevant for extensive systems, as medium-growing genotypes tend to show greater robustness to welfare challenges than their fast-growing counterparts. The absence of interaction effects between genotype and outdoor access highlights that both factors contribute independently to welfare, with outdoor access enhancing behavioral welfare and genetic selection supporting resilience against environmental stressors. Overall, while JA787′s slower growth rate appears to offer some welfare advantages, particularly in extensive rearing systems, its slightly higher susceptibility to plumage damage under specific conditions suggests a need for tailored management strategies to optimize welfare outcomes for this genotype.

The lack of identified significant interaction effects between husbandry factors, such as enrichment, lucerne provision, stocking density, genetics, and outdoor access, suggest that these factors influence welfare

Table 10
ANOVA effects of perch enrichment presence or absence and outdoor access on Hubbard JA787 hybrid welfare indicators (F and P value).

Welfare Indicator	Enrichment	Outdoor access	Enrichment * Outdoor access
Comb wounds	$F = 1.85, P = 0.20$	$F = 3.85, P = 0.07$	$F = 2.00, P = 0.13$
Dirtiness	$F = 2.25, P = 0.15$	$F = 3.20, P = 0.06$	$F = 1.32, P = 0.19$
FPD	$F = 3.60, P = 0.02$	$F = 4.15, P = 0.03$	$F = 1.75, P = 0.11$
Hock burn	$F = 1.65, P = 0.20$	$F = 2.80, P = 0.08$	$F = 0.78, P = 0.33$
Lameness	$F = 3.80, P = 0.09$	$F = 3.25, P = 0.07$	$F = 1.85, P = 0.49$
Plumage damage	$F = 4.10, P = 0.06$	$F = 2.95, P = 0.07$	$F = 1.70, P = 0.17$
Skin injuries	$F = 2.60, P = 0.09$	$F = 3.05, P = 0.08$	$F = 0.90, P = 0.47$
Toe damage	$F = 3.55, P = 0.03$	$F = 3.85, P = 0.06$	$F = 1.80, P = 0.21$

Table 9
Mean values and standard errors for welfare indicators in Hubbard JA757 hybrid under different conditions of enrichment and outdoor access.

Welfare Indicator	Enrichment		Outdoor access		Enrichment* Outdoor access			
					No perch		Perch	
	No perch ($N = 60$)	Perch ($N = 60$)	No access ($N = 60$)	Access ($N = 60$)	No access ($N = 30$)	Access ($N = 30$)	No access ($N = 30$)	Access ($N = 30$)
Comb wounds	0.05 ± 0.03	0.06 ± 0.03	0.04 ± 0.02	0.06 ± 0.02	0.04 ± 0.02	0.07 ± 0.03	0.05 ± 0.02	0.08 ± 0.03
Dirtiness	0.14 ± 0.05	0.15 ± 0.04	0.13 ± 0.04	0.16 ± 0.05	0.12 ± 0.04	0.15 ± 0.04	0.14 ± 0.05	0.16 ± 0.05
FPD	$0.10^{b*} \pm 0.04$	$0.11^{a} \pm 0.03$	$0.13^{a} \pm 0.03$	$0.12^{b} \pm 0.04$	0.08 ± 0.03	0.11 ± 0.03	0.15 ± 0.03	0.09 ± 0.03
Hock burn	0.04 ± 0.02	0.05 ± 0.02	0.03 ± 0.01	0.06 ± 0.02	0.02 ± 0.01	0.05 ± 0.02	0.04 ± 0.02	0.06 ± 0.02
Lameness	$0.03^{a} \pm 0.01$	$0.02^{b} \pm 0.01$	0.02 ± 0.01	0.03 ± 0.01	0.01 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.01
Plumage damage	$0.03^{b} \pm 0.02$	$0.05^{a} \pm 0.02$	$0.04^{b} \pm 0.02$	$0.05^{a} \pm 0.02$	0.02 ± 0.01	0.05 ± 0.02	0.04 ± 0.02	0.06 ± 0.02
Skin injuries	0.00 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.01
Toe damage	0.06 ± 0.02	0.07 ± 0.02	0.05 ± 0.02	0.09 ± 0.02	0.05 ± 0.02	0.07 ± 0.02	0.06 ± 0.02	0.08 ± 0.02

* Different superscript letters within rows, under each factor or interaction of factors, indicate statistically significant differences between groups ($P \leq 0.05$).

Table 11
Mean values and standard errors for welfare indicators in Hubbard JA787 hybrid under different conditions of enrichment and outdoor access.

Welfare Indicator	Enrichment		Outdoor access		Enrichment* Outdoor access			
					No perch		Perch	
	No perch (N = 60)	Perch (N = 60)	No access (N = 60)	Access (N = 60)	No access (N = 30)	Access (N = 30)	No access (N = 30)	Access (N = 30)
Comb wounds	0.06 ± 0.04	0.07 ± 0.03	0.06 ± 0.02	0.08 ± 0.03	0.05 ± 0.03	0.06 ± 0.02	0.07 ± 0.04	0.08 ± 0.02
Dirtiness	0.13 ± 0.04	0.14 ± 0.04	0.13 ± 0.04	0.14 ± 0.03	0.12 ± 0.04	0.14 ± 0.04	0.13 ± 0.04	0.15 ± 0.05
FPD	0.09^{b*} ± 0.03	0.12^{a} ± 0.02	0.11^{a} ± 0.03	0.10^{b} ± 0.04	0.09 ± 0.03	0.10 ± 0.03	0.12 ± 0.02	0.10 ± 0.02
Hock burn	0.04 ± 0.02	0.05 ± 0.01	0.03 ± 0.02	0.04 ± 0.02	0.02 ± 0.01	0.04 ± 0.02	0.05 ± 0.01	0.04 ± 0.02
Lameness	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.04 ± 0.02	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.02	0.03 ± 0.01
Plumage damage	0.06 ± 0.03	0.08 ± 0.02	0.06 ± 0.02	0.07 ± 0.02	0.06 ± 0.01	0.05 ± 0.02	0.08 ± 0.02	0.09 ± 0.02
Skin injuries	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.01	0.01 ± 0.01
Toe damage	0.04^{b} ± 0.03	0.08^{a} ± 0.02	0.06 ± 0.02	0.05 ± 0.02	0.05 ± 0.02	0.04 ± 0.02	0.07 ± 0.02	0.08 ± 0.02

* Different superscript letters within rows, under each factor or interaction of factors, indicate statistically significant differences between groups ($P \leq 0.05$).

Table 12
ANOVA effects of Hubbard hybrid and outdoor access on welfare indicators (F, P value).

Welfare Indicator	Genetics	Outdoor access	Genetics * Outdoor access
Comb wounds	$F = 1.90$, $P = 0.18$	$F = 3.90$, $P = 0.04$	$F = 2.10$, $P = 0.13$
Dirtiness	$F = 2.35$, $P = 0.11$	$F = 3.40$, $P = 0.06$	$F = 1.35$, $P = 0.21$
FPD	$F = 3.70$, $P = 0.03$	$F = 4.25$, $P = 0.02$	$F = 1.80$, $P = 0.16$
Hock burn	$F = 1.60$, $P = 0.20$	$F = 2.90$, $P = 0.05$	$F = 0.77$, $P = 0.43$
Lameness	$F = 3.95$, $P = 0.07$	$F = 3.35$, $P = 0.07$	$F = 1.95$, $P = 0.14$
Plumage damage	$F = 4.05$, $P = 0.03$	$F = 2.85$, $P = 0.06$	$F = 1.75$, $P = 0.18$
Skin injuries	$F = 2.70$, $P = 0.08$	$F = 3.15$, $P = 0.08$	$F = 0.88$, $P = 0.37$
Toe damage	$F = 3.65$, $P = 0.06$	$F = 3.95$, $P = 0.06$	$F = 1.85$, $P = 0.17$

outcomes independently rather than synergistically. This result is noteworthy, as welfare studies often assume that combined factors produce amplified or compounded effects (Dawkins and Layton, 2012; Hartcher and Lum, 2020; Stadig et al., 2017). For instance, lower stocking density improved footpad health and reduced comb wounds in Ross 308 chickens, while lucerne provision reduced FPD and aggression-related injuries. These effects, however, did not overlap or amplify each other when combined. Likewise, outdoor access improved welfare indicators in Hubbard hybrids but did not interact significantly with perch enrichment or genotype. This lack of interaction aligns with findings by Buijs et al. (2009) and de Jong et al. (2022), which suggest that the effects of individual welfare interventions often address specific dimensions of welfare rather than compounding into broader improvements. The controlled nature of this study may also have minimized environmental variability, reducing the likelihood of complex interaction effects often observed in commercial settings. These results support a modular approach to welfare interventions, emphasizing that targeted improvements in diet, density, or environmental enrichments can independently contribute to better welfare outcomes without relying on multifactorial combinations. This conclusion is consistent with previous research advocating for context-specific, genotype-focused welfare strategies (Stadig et al., 2017; Hartcher and Lum, 2020). Targeted approach can help producers avoid unnecessary costs and management challenges while still meeting welfare objectives, emphasizing that individual factors, rather than an all-encompassing system, can be more effective and flexible in improving broiler welfare across diverse production environments.

While this study provides valuable insights into the effects of husbandry practices on welfare indicators in broilers, several limitations should be noted. The controlled environment may limit the generalizability of results to commercial settings, where variability in environmental conditions, flock sizes, and management practices could impact outcomes differently. Additionally, focusing on only three genotypes: Ross 308 and Hubbard hybrids may not fully represent welfare outcomes in other broiler genotypes, particularly within the diverse range of slow-growing hybrids that may respond uniquely to similar interventions (Marchewka et al., 2020). Conducting welfare assessments primarily at the end of the production cycle also restricts understanding of how welfare indicators evolve over time. Continuous monitoring of welfare indicators could provide a more comprehensive picture of welfare trajectories across the growth period. Moreover, while specific factor combinations were tested, a full factorial design was not used, limiting the ability to capture complex relationships between multiple factors

Table 13
Mean values and standard errors for welfare indicators in Hubbard hybrids under provision or not of outdoor access.

Welfare Indicator	Genetics		Outdoor access		Genetics* Outdoor access			
					JA757		JA787	
	JA757 (N = 60)	JA787 (N = 60)	No access (N = 60)	Access (N = 60)	No access (N = 30)	Access (N = 30)	No access (N = 30)	Access (N = 30)
Comb wounds	0.05 ± 0.03	0.07 ± 0.03	0.07^{a*} ± 0.03	0.06^{b} ± 0.02	0.06 ± 0.02	0.01 ± 0.02	0.07 ± 0.03	0.08 ± 0.03
Dirtiness	0.14 ± 0.05	0.15 ± 0.04	0.13 ± 0.04	0.16 ± 0.05	0.12 ± 0.04	0.14 ± 0.05	0.15 ± 0.04	0.16 ± 0.05
FPD	0.10^{b} ± 0.04	0.11^{a} ± 0.03	0.14^{a} ± 0.03	0.10^{b} ± 0.04	0.08 ± 0.03	0.11 ± 0.03	0.15 ± 0.03	0.10 ± 0.03
Hock burn	0.04 ± 0.02	0.05 ± 0.02	0.03^{b} ± 0.01	0.06^{a} ± 0.02	0.02 ± 0.01	0.04 ± 0.02	0.05 ± 0.02	0.06 ± 0.02
Lameness	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.01 ± 0.01	0.04 ± 0.01	0.02 ± 0.01	0.03 ± 0.01
Plumage damage	0.03^{b} ± 0.02	0.05^{a} ± 0.02	0.04 ± 0.02	0.05 ± 0.02	0.02 ± 0.01	0.04 ± 0.02	0.05 ± 0.02	0.06 ± 0.02
Skin injuries	0.00 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.01 ± 0.00	0.01 ± 0.01	0.01 ± 0.01
Toe damage	0.06 ± 0.02	0.07 ± 0.02	0.05 ± 0.02	0.09 ± 0.02	0.05 ± 0.02	0.08± 0.02	0.07 ± 0.02	0.09 ± 0.02

* Different superscript letters within rows, under each factor or interaction of factors, indicate statistically significant differences between groups ($P \leq 0.05$).

across broiler types. Future studies should explore the long-term welfare impacts of combined husbandry practices across different broiler genotypes to develop flexible guidelines that address genetics, diet, enrichment, and environmental access for sustainable, welfare-focused poultry production systems (Dawkins and Layton, 2012).

The findings of this study have implications for commercial broiler farming and consumer perceptions of welfare practices. Implementing interventions such as outdoor access or lucerne provision on a large scale presents logistical and economic challenges, particularly in intensive systems where space and costs are tightly managed. For instance, outdoor access, though beneficial for medium-growing genotypes, may increase land requirements and management complexity, limiting its feasibility in high-density production systems (Fanatico et al., 2016). Furthermore, consumer expectations often align outdoor access and enrichment with higher welfare, yet this study highlights that not all interventions yield universally positive outcomes, such as the increased plumage damage observed with perches in Ross 308 chickens. This underscores the importance of transparent communication about the trade-offs of specific welfare practices in labeling and marketing strategies (Erian and Phillips, 2017). Additionally, while interventions like reduced stocking density and lucerne supplementation improve welfare, they may also contribute positively to environmental sustainability by promoting healthier litter conditions, potentially reducing ammonia emissions, and integrating with circular farming systems (Bilgili et al., 2009; Stadig et al., 2017). These results suggest that welfare strategies need to balance consumer-driven expectations, environmental sustainability, and practical feasibility in commercial operations.

Conclusion

This study provides insights into the effects of targeted husbandry practices on welfare indicators in broiler chickens under varying conditions. Results indicate that perch enrichment and reduced stocking densities positively impacted plumage damage and footpad health, particularly in indoor systems. In Ross 308 chickens lucerne provision improved welfare indicators by reducing comb wounds. Additionally, Hubbard hybrids exhibited improved welfare outcomes in environments with outdoor access. While each factor independently enhanced welfare, no significant interactions were found, suggesting that these practices primarily offer additive rather than synergistic benefits. These findings indicated that targeted modifications in enrichment, diet, and outdoor access effectively enhance welfare, providing practical solutions for varied production systems.

Declaration of competing interest

No Conflict of Interest.

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