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Providing environmental enrichments affects activity and performance, but not leg health in fast- and slower-growing broiler chickens

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ABSTRACT

Effects of environmental enrichment on activity, behaviour, walking ability, contact dermatitis and performance were investigated in fast- and slower-growing broiler chickens. A total of 840 day-old male broilers, 420 of a fast-growing strain (Ross 308) and 420 of a slower-growing strain (Hubbard JA757), were housed in a 2 × 2 factorial arrangement, using a complete randomized design. Broilers were housed in 28 pens of 3 m^2 in one climate-controlled room. Half of the pens per strain were enriched (EE) with barrier perches, ramps, platforms and a dustbathing area, and the other half of the pens were not enriched (NE). In the EE pens, also black soldier fly larvae were provided daily in the dustbathing area and broilers in NE pens received an additional protein-fat mix, to achieve similar energy and nutrient intake compared to the EE treatment. Behaviour was observed by scan sampling and focal sampling in weeks 2, 4, 5 and 7. Walking ability, footpad dermatitis and hock burn were measured in three broilers per pen at a body weight of 1.7 and 2.6 kg. Performance was determined weekly. Results showed that in the enriched environment, at the same age slower-growing broilers made more use of provided enrichment materials than fast-growing broilers ($P < 0.001$; $\Delta = +13.5$ %). Providing enrichment decreased the proportion of slower-growing chickens standing idle, whereas this effect was not found for fast-growing broiler chickens ($P = 0.006$; $\Delta =$ -2.8 % for slower-growing broilers). Furthermore, at the same age, more slower-growing broilers were active ($\Delta = +4.5$ %) compared to fast-growing broilers, whereas fast-growing broilers showed more sitting idle ($\Delta = +4.2$ %) and ingestion behaviour ($\Delta = +2.8$ %) than slower-growing broilers in both EE and NE pens ($P < 0.05$). Broilers of both strains in EE pens showed longer duration of activity ($P < 0.05$; $\Delta = +11.3$ %) compared to broilers in NE pens. No effects of enrichment or strain were observed for walking ability and contact dermatitis. Fast-growing broilers and broilers in NE pens had a higher average body weight, a higher average daily gain and a higher feed intake than slower-growing broilers and broilers in EE pens, respectively. In conclusion, environmental enrichment was most used by slower-growing broilers and providing enrichments increased activity to a similar extent in both strains. However, providing enrichments did not improve walking ability and had an adverse effect on performance in both strains.

1. Introduction

Due to genetic selection for efficient growth and improvements in farm management and nutrition over the years, broiler chickens nowadays grow in a relatively short period to slaughter weight (Zuidhof et al., 2014). This efficient growth, in combination with the relatively high body weight and low activity level, has been associated with the development of leg problems: impaired walking ability (Bessei, 2006; EFSA, 2010; Tahamtani et al., 2018) and contact dermatitis on feet and hocks (Bessei, 2006; EFSA, 2010). Leg problems have a negative effect on broiler welfare, because of pain and discomfort and difficulties to perform natural behaviours (Mc Geown et al., 1999; Weeks et al., 2000;

Abbreviations: BSFL, black soldier fly larvae; EE, enriched environment; NE, non-enriched environment; SLOW, slower-growing broiler strain; FAST, fast-growing broiler strain.

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Caplen et al., 2013; Hothersall et al., 2016). Since leg problems and low levels of activity are interrelated, it has been suggested that stimulating physical activity of broilers may be a method to prevent leg problems and consequently improve broiler welfare (Kestin et al., 1992; Prayitno et al., 1997; Reiter and Bessei, 2009; Stojcic and Bessei, 2009).

Broiler activity can be stimulated through an enriched environment, by for example including (specific) bedding material, perches and ramps in the house, but also by providing feed, such as live insects, in the litter (Simsek et al., 2009; Pichova et al., 2016; Baxter et al., 2018b; Riber et al., 2018; Ipema et al., 2020a). This also increases the opportunity to perform species-specific behaviours, such as perching, foraging and dustbathing (Bessei, 2006; Riber et al., 2018). Studies have shown that increased physical activity of broiler chickens by altering the lay-out of pens, for example by adding barriers, increasing the distance between feeding and drinking places, or by adding bales and/or platforms or perches, improved walking ability in fast-growing broiler chickens (Bizeray et al., 2002a; 2002b; Reiter, 2004; Kaukonen et al., 2017; Vasdal et al., 2019), although these effects were not found in all studies (de Jong and Gunnink, 2019; Pedersen et al., 2020). Similarly, environmental enrichment is suggested to reduce the risk for footpad dermatitis and hock burn, e.g. because of reduced contact of broilers with the litter when platforms or perches are provided (Ventura et al., 2010), but also these effects are not always found (Pedersen and Forkman, 2019).

Nowadays, slower-growing broiler strains are increasingly used for meat production, especially in North-Western Europe (Vissers et al., 2019). Slower-growing broilers need more time to reach the appropriate slaughter weight than fast-growing broilers. Consequently, leg bones have longer time to develop, resulting in a more mature and robust skeleton. Because of a better developed skeleton, weight load of slower-growing broilers might have less impact, resulting in better walking ability in slower-growing broilers compared to fast-growing ones (Bokkers and Koene, 2003; Dixon, 2020; Rayner et al., 2020). Slower-growing broilers are therefore also suggested to make better use of environmental enrichment compared to fast-growing broiler chickens (Bokkers and Koene, 2003; Malchow et al., 2019; Rayner et al., 2020). Finally, because of the higher activity of slower-growing broilers they spend less time in contact with litter, which reduces the risk to develop footpad dermatitis and hock burn (Rayner et al., 2020).

The objective of the present study was to investigate effects of environmental enrichment on activity, behaviour, performance, walking ability, footpad dermatitis and hock burn of fast and slower-growing broilers. Potentially successful environmental enrichments to increase physical activity in broiler chickens were selected from scientific literature, and included platforms with ramps (Norring et al., 2016; Kaukonen et al., 2017), barrier perches placed in between feed and water resources (Bizeray et al., 2002a; Ventura et al., 2010), a maximum distance between feed and water (Reiter and Bessei, 2009; Bach et al., 2019), a dustbathing area (Baxter et al., 2018a), and feeding live insects (Pichova et al., 2016; Ipema et al., 2020a). All these environmental enrichments were combined to achieve the maximum effect on broiler chicken activity. We hypothesised that the combined environmental enrichments would have a positive effect on physical activity in both fast and slower-growing broilers, and that this effect would be larger in slower than in fast-growing broilers as slower-growing broilers may be better able to use the provided enrichment materials. Therefore, we also hypothesised that enriched slower-growing broilers would have the best walking ability and the lowest prevalence of contact dermatitis compared to the non-enriched and fast-growing broiler chickens.

2. Materials and methods

2.1. Experimental setup, animals and housing

This experiment was carried out in a 2 × 2 factorial arrangement, using 420 male fast-growing Ross 308 broilers (FAST) and 420 male slower-growing Hubbard JA757 broilers (SLOW) housed at the research facility of Wageningen Bioveterinary Research (Lelystad, The Netherlands). Only male chickens were used to reduce variation within a pen and because males are usually more susceptible to develop leg problems than females (Dixon, 2020). Day-old chicks were randomly allocated within each strain to either an environmentally enriched pen (EE) or a non-enriched pen (NE). Four treatment groups (EE – FAST, EE – SLOW, NE – FAST, NE – SLOW) were randomly allocated to 28 pens within one experimental room; each treatment was replicated seven times.

All broilers originated from a commercial hatchery (Probroed, Groenlo, The Netherlands) and both strains were from parent stocks of 41 weeks of age. Broilers were housed in groups of 30 per pen (3 × 1 m). Upon arrival, room temperature was set at 34 °C and gradually decreased by 1 °C per day to a constant temperature of 18 °C at 40 days (d) of age and onwards. Relative humidity was kept between 60–80% from d 1–7 of age and between 40–80% from d 8 until the end of the experiment. Feed and water were provided *ad libitum* via one trough feeder (length 1 m and placed outside the pen) and three drinking nipples per pen. Broilers were exposed to a light-dark regimen of 20 L:4D from d 1–6, which gradually changed to 18 L:6D at d 7 and onwards, with a continuous dark period between 23:30 – 05:30.

Both strains received the same three-phase commercially available diet. The starter diet was provided between d 0 and 14 and included 2925 kcal/kg metabolic energy (ME), 201.4 g/kg crude protein (CP) and 11.7 g/kg digestible lysine (dLys). The grower diet was provided between d 15 and 35 of age and included 2975 kcal/kg ME, 178.2 g/kg CP and 10.5 g/kg dLys. The finisher diet was provided when broilers were 35 (FAST) or 51 (SLOW) days of age and included 3025 kcal/kg ME, 175.6 g/kg CP and 10.0 g/kg dLys. To achieve similar energy and nutrient intake for broilers in EE pens that received black soldier fly larvae (BSFL) as enrichment (see below), broilers in NE pens received an additional protein-fat mix of 91 % soybean, 8.1 % palm oil and 0.9 % limestone. This additional protein-fat mix was pelleted and provided in the feeding troughs, at the same time when BSFL were provided in EE pens. The amount of BSFL provided to broilers in EE pens and protein-fat mix provided to broilers in NE pens was determined daily and calculated based on fresh weight of expected feed intake. Amounts were 10 % of the expected feed intake on d 0 and 1, 15 % of the expected feed intake on d 2–4, and 10 % of the expected feed intake on d 5–7. The higher amount of BSFL in the first days was to ensure that each chicken could eat larvae. From d 8 onwards, the feeding level of BSFL and protein-fat mix was always 5% of the expected feed intake.

FAST broilers were sent to slaughter at d 38 and SLOW broilers at d 53, with a target live weight of 2.6 kg for both strains at slaughter age. For other purposes, three broilers were removed from the pens with FAST birds at d 32 and the pens with SLOW birds at d 38 of age (target weight 1.7 kg for both strains; results are not included in this paper).

2.2. Treatments

EE pens had wood shavings as bedding material. In the middle of the pen a dustbathing area with moss-peat was created (100 × 100 cm), separated by two barrier perches (square shape), which were adjustable in height (in fixed steps of 4 cm, with maximum of 16 cm from day 21 onward). Wood shavings and moss-peat were provided up to a height of 7.5 cm. In addition, two wooden platforms (100 × 20 cm; non-perforated, without substrate) were included in EE pens, one at each side of the pen and each equipped with a wooden ramp (200 × 20 cm, angle of 11.5°) (Fig. 1). It was estimated that 6 broilers could sit on each barrier perch, thus 12 in total per pen (based on 16 cm bird width at the highest age (Giersberg et al., 2019)), that 5 broilers could sit on the platform and 9 on the ramp (based on a surface of 433.6 cm^2 per broiler at the highest age (Spindler et al., 2016)). In the dustbathing area of the EE pens, live BSFL were provided once a day, around 11.00 h AM. Feed and water were provided at the short ends of the pens, creating a

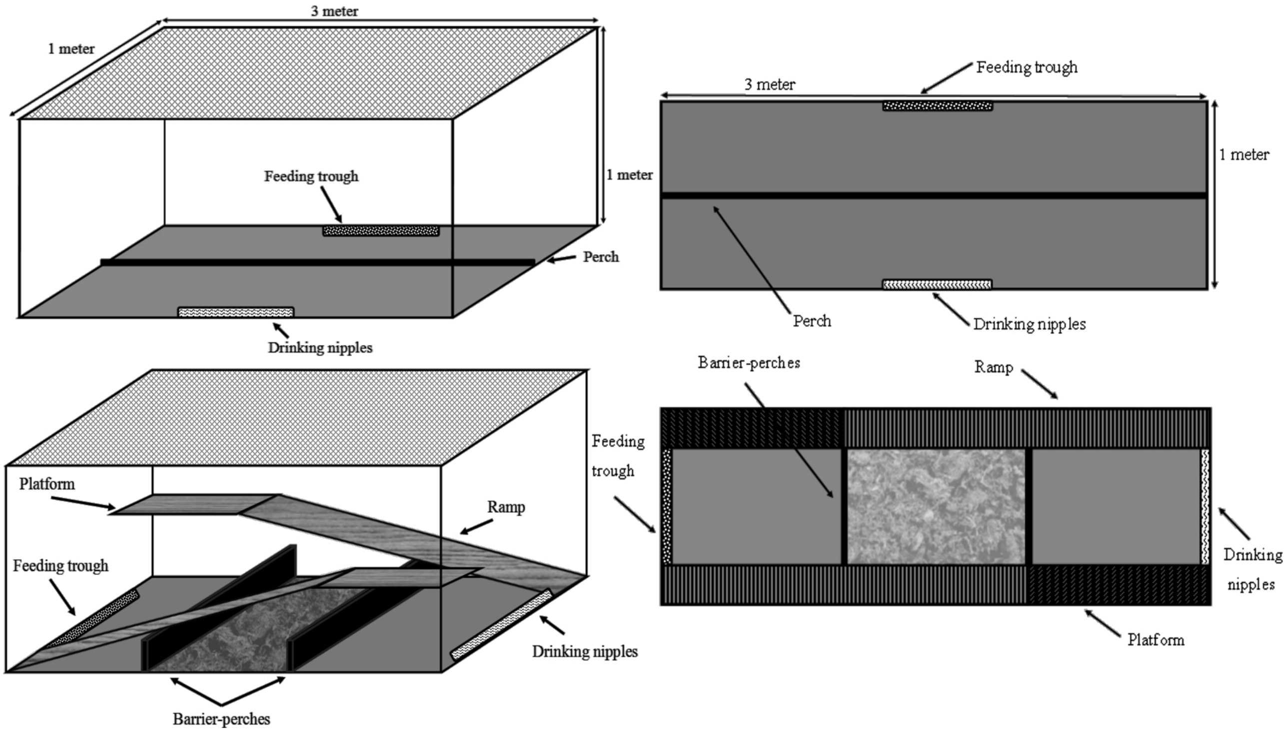

Fig. 1. Side view (left) and top view (right) of a control pen (top) and an enriched pen (bottom). Feeding troughs, drinking nipples and elevated structures are pointed in the illustrations. Both pens had wood shavings as bedding material. Enriched pens had supplemented moss peat between the barrier perches (mottled gray area). The recorded height of both beddings were 1 cm in week 1, 4 cm in week 2 and up to 7.5 cm high from week 3 onwards.

maximum distance of 3 m between feeding troughs and drinking nipples.

NE pens had wood shavings as bedding material, a single perch (length 3 m, height 2 cm) in the central area of the pen, and feed and water were provided at the long ends of the pens, creating the smallest distance between feeding troughs and drinking nipples (1 m).

2.3. Measurements

2.3.1. Performance, walking ability and contact dermatitis

Broilers were weighed and feed intake (FI) was determined once a week at pen level. Total feed conversion ratio (FCR) was calculated, in addition to average BW (ABW), average daily gain (ADG), average daily FI (ADFI) and FCR calculated on a weekly basis. Mortality was recorded daily. At d31 (FAST), 37 (FAST and SLOW) and 51 (SLOW), three broilers per pen were scored for gait, footpad dermatitis (FPD) and hock burn (HB); this was at comparable weights for both strains (±1.6 kg and ±2.5 kg target weight respectively). Gait was scored on a 0–5 scale according to Welfare Quality®, with 0 as a perfect gait and 5 as incapable of walking (Welfare Quality, 2009). FPD and HB scores of the same broilers were scored on a 0–4 scale according to Welfare Quality®, with 0 being no lesions and 4 being severe FPD or HB (Welfare Quality, 2009).

2.3.2. Behaviour

Both instantaneous scan sampling and focal sampling of behaviour was performed in 2 sessions (morning (from 9 h onward) and afternoon (from 13 h onward)), by one trained observer. At 11 h, morning observations were paused, because BSFL were provided and observations continued at 11:30 h.

Instantaneous scan sampling was used for group level observations at d 9, 24, 31 (both strains) and d 45 (only SLOW). The observer walked slowly to a pen, waited for 1 min in front of the pen to habituate the birds, and then counted the number of broilers performing each of the following behaviours per pen: sitting idle (i.e. without any other activity), standing idle (i.e. without any other activity), eating (pecking at the feeder), drinking (pecking at the nipple or drip cup), locomotion (walking, running, or jumping, either or not with wing-flapping), sitting and ground pecking, foraging (alternating pecking and scraping in the litter), aggression (hopping, threatening, kicking, or pecking directed to a pen mate), comfort (preening, wing flapping, stretching, or shaking feathers), dustbathing (all elements according to van Liere, 1991) and other (all other behaviours). In addition, the observer counted the number of broilers using the enrichments in each pen, which comprised the number of broilers on and under the platform including the ramps, on the perches, and performing dustbathing in the dustbathing area. Thereafter, the observer moved to the next pen, waited again for 1 min and repeated the scan. This was repeated until all pens were observed in a session.

Focal sampling was used to record the behaviour of two broilers per pen at d 10, 25, 32 (both strains) and d 46 of age (only SLOW). Two randomly assigned chickens per pen received a coloured spot on the head (red or green) and were observed at all ages. Other chickens in a pen received a standard mark (blue) to prevent deviant behaviour. In case a focal chicken died, it was replaced by another randomly chosen chicken. A handheld computer (Psion Workabout Pro 4, Psion, PLC, London, UK) with The Observer software package (The Observer XT 10.5, Noldus Information Technology B.V., Wageningen, the Netherlands) was used to score individual behaviours. After a habituation of 1 min, each focal chicken was observed for 120 s and all behaviours were recorded according to the ethogram in Table 1. Both chickens in a pen were observed before moving to the next pen.

2.4. Statistical analysis

Data were analysed at pen level, using statistical software SAS 9.4 (Statistical Analysing Software, Inc.). Normality of the data was assessed based on model residuals using the Shapiro-Wilk test. Data that did not meet assumptions of normality were log transformed. Performance data (ABW, ADG, FCR, and ADFI) were analysed using a General Linear

Model (GLM) procedure with model [1]:

$$Y = \mu + \text{enrichment} + \text{strain} + \text{enrichment*strain} + \varepsilon \quad (1)$$

Where Y = dependent variable, μ = overall mean, enrichment = effect of enrichment (NE, EE), strain = effect of strain (FAST, SLOW), enrichment*strain = interaction between enrichment and strain, Ɛ is the residual error term. In weeks 7 and 8, only SLOW broilers were present and strain and the interaction effect were excluded from the model.

The GLIMMIX-procedure was used for analysis of enrichment effects on walking ability, footpad lesions and hock burn, using model [2]:

$$Y = \mu + \text{enrichment} + \text{strain} + \text{enrichment*strain} + BW + \varepsilon \quad (2)$$

Where Y = dependent variable, μ = overall mean, enrichment = effect of enrichment (NE, EE), strain = effect of strain (FAST, SLOW), enrichment*strain = interaction between enrichment and strain, BW is the effect of body weight used as a covariate, Ɛ is the residual error.

Due to high occurrence of zero's for some behaviours, behavioural data were aggregated and expressed as percentage of broilers performing a certain behaviour or behavioural category. Scan sampling data was grouped into the categories ingestion (eating and drinking), active (sum of locomotion, sitting and ground pecking, foraging, aggression and other) and comfort (dustbathing and comfort behaviour) in addition to the behaviours sitting idle and standing idle. Focal sampling data was grouped into the categories active, resting, ingestion and comfort behaviour (see Table 1). Only these behavioural categories in addition to the postures sitting and standing were included in the analyses, and expressed as percentages of total time observed. For analysis of scan sampling data (proportion of chickens performing behaviour) and focal sampling data (proportion of time spent on behaviour) the MIXED-procedure was used with model [3]:

$$Y = \mu + \text{enrichment} + \text{strain} + \text{enrichment*strain} + \text{session} + \text{age} + \text{age*enrichment} + \text{age*strain} + \text{age*enrichment*strain} + \varepsilon \quad (3)$$

Where Y = dependent variable, μ = overall mean, enrichment = effect of enrichment (NE, EE), strain = effect of strain (FAST, SLOW), enrichment*strain = interaction between enrichment and strain, session is observation session (morning or afternoon), age = age of the broilers (9, 24, and 31 for group behaviour and 10, 25 and 32 for individual behaviour), age*enrichment = interaction between age and enrichment, age*strain = interaction between age and strain, age*enrichment*strain = 3-way interaction between age, enrichment and strain, Ɛ = residual error. Non-significant three-way interactions and two-way interactions were stepwise deleted from the model. The final observation day (only SLOW; d 45 for scan sampling and d 46 for focal sampling) was analysed separately with only enrichment and session in the model. Three-way interactions were included when significant. Two-way interactions were included when significant or when the three-way interaction was significant.

For analysing enrichment use (only enriched pens), percentage of broilers at each location was analysed, using MIXED-procedure based on model [4]:

$$Y = \mu + \text{strain} + \text{session} + \text{age} + \varepsilon \quad (4)$$

Where Y = dependent variable, strain = effect of strain (FAST, SLOW), session = effect of observation session (morning, afternoon), age = age of broilers (d 9, 24, 31), Ɛ = residual error

Also here, from the final observation day (d 45, only SLOW) were analysed separately, with only session in the model.

As fast- and slower-growing broiler chickens had equal BW (±1.1 kg) at d 24 (fast-growing) and d 31 (slower-growing), we also compared behaviour of fast- and slower-growing chickens at this equal BW. For group behaviour data (scan sampling) this comprised data obtained at day 24 (fast-growing) and day 31 (slow-growing), and for individual behaviour data (focal sampling) this comprised data obtained at day 25 (fast-growing) and day 32 (slow-growing). For both comparisons, the MIXED-procedure was used based on model [5]:

$$Y = \mu + \text{enrichment} + \text{strain} + \text{enrichment*strain} + \text{session} + \varepsilon \quad (5)$$

Where Y = dependent variable, μ = overall mean, enrichment = effect of enrichment (NE, EE), strain = effect of strain (FAST, SLOW), enrichment*strain = interaction between enrichment and strain, session = effect of observation session (morning, afternoon), Ɛ = the residual error.

Table 1
Ethogram used for scoring individual behaviour (focal sampling).

Posture	Description
Sitting	Sitting with hocks resting on ground/enrichment or lying
Standing	Bird maintains upright position on extended legs (including ground and enrichment)

Category	Behaviour	Description
Resting	Idle	Bird is standing or sitting without any other activity (inactive).
Ingestion	Ingestion	Eating (pecking directed at the feeder, with head above or in the feeder) or drinking (pecking directed at the drinking nipple, or drinking out of the cup beneath the drinking nipple).
Active	Locomotion	Walking (relatively low-speed displacement of bird on ground) or running (higher speed displacement of bird on ground).
	Perching	Bird's feet are grasping the barrier. Breast of bird should be in contact with barrier or bird is standing on the perch for longer than 5 s.
	Fight	Hopping or jumping onto another bird, might be accompanied by delivering one or more vigorous kicks at opponent or delivering one or more aggressive pecks towards the opponent
	Scratching	Scraping (with the claws) directed at ground or litter
	Ground pecking	Pecking directed at ground or litter
	Jumping	Both feet are off the floor and touch the floor again, accompanied by no or single wing-flapping. Bird is moving from different levels.
	Flying	Starts when bird extends and flaps her wings and moves a distance through the air
	Wing- flapping	Bilateral up-and-down wing flapping. Bird shakes her wings at least twice.
	Aggressive pecking	Vigorous pecks directed toward another bird (usually directed to the head), not preceded or accompanied by hopping, jumping or kicking
	Other	All other behaviours not mentioned above
Comfort	Preening	Grooming of own feathers with the beak.
	Dustbathing	Performed with fluffed feathers while lying, head rubbed on floor, wings opened, scratching at ground (van Liere, 1991)
	Stretching	Stretching a wing and/or a leg

Data are expressed as LSmeans ± pooled standard error of the mean (SEM) for the GLM and MIXED procedures and as means ± SE for the GLIMMIX procedure. P-values ≤ 0.05 were considered significant.

2.5. Ethical note

The study was carried out in compliance with the ethical guidelines of the International Society of Applied Ethology (Sherwin et al., 2003). The experiment was approved by the Central Commission of Animal Experiments, The Hague, The Netherlands (approval no. AVD 401002016866) and the Institutional Animal Care and Use Committee.

3. Results

3.1. Performance

Mortality did not differ between the treatments and 45 birds died in total (including selection) (12, 10, 11, 12 chickens, respectively for EE-FAST, EE-SLOW, NE-FAST and NE-SLOW). Performance results are summarized in Table 2. An interaction between strain and enrichment was found for ADG in week 2 (d 8−17) and for ADFI in week 4 (d 23−28) ($P < 0.05$); no differences were found between slower-growing broilers in EE and NE pens, whereas for the fast-growing strain, broilers in NE pens had a higher ADG ($\Delta = +3$ g) and a higher ADFI ($\Delta = +8.2$ g) than broilers in EE pens. For all performance variables, strain effects were found for all ages ($P < 0.001$), except for FCR in week 5 (d 29−37). ABW, ADG and ADFI were significantly higher for FAST than for SLOW broilers, where FCR was significantly higher for SLOW than for FAST broilers (Table 2). Pen enrichment affected performance ($P \leq 0.05$). ABW from day 17 and onwards, ADG of week 2 (d 8−16) and from week 5 onwards (d 29–53), FCR of week 1 (d 0−7), and ADFI for all weeks, except for week 2 (d 8−16), were significantly higher for broilers in NE pens than for broilers in EE pens (Table 2).

3.2. Behaviour

3.2.1. Scan sampling

Table 3 presents the results when treatments were compared at the same age. An interaction effect between strain and enrichment was only found for standing idle on d 9, 24 and 31 ($P < 0.001$); NE-FAST broilers showed least standing idle and NE-SLOW broilers showed most standing idle ($\Delta = 4.8$ %), with NE-FAST and EE-SLOW in between. Strain effects ($P \leq 0.05$) were found for sitting idle, ingestion and active behaviour on d 9, 24 and 31. FAST broilers showed higher percentages of sitting idle ($\Delta = +4.2$ %) and ingestion behaviours ($\Delta = +2.8$ %) compared to SLOW broilers whereas more SLOW broilers were active compared to FAST broilers ($\Delta = +4.5$ %). Further, SLOW broilers in EE pens showed more active behaviours than SLOW broilers in NE pens on d 45 ($\Delta = +4.2$ %; $P = 0.05$).

Session (morning or afternoon) did not have an effect on behaviour. At d 9 of age, ingestion behaviour was more observed as compared to d 24 and 31 ($P < 0.05$), regardless of strain (Table 3). A three-way interaction between age, strain and enrichment was found for sitting idle, standing idle and active behaviour ($P < 0.05$; data not shown),

Table 2
Effects of strain, pen enrichment and their interaction on performance, shown in least square means and pooled SEM. Weighing intervals correspond to the intervals indicated in the table. FAST = fast-growing broiler; SLOW = slower-growing broiler; EE = enriched pen, NE = non-enriched pen. From 38 days of age onwards only SLOW broilers were in the experiment.

Variable		Strain			Enrichment			Interaction					P-value		
		FAST	SLOW	SEM	EE	NE	SEM	EE-FAST	NE-FAST	EE-SLOW	NE-SLOW	SEM	P_{strain}	$P_{enrich\text{-}ment}$	$P_{strain*enrichment}$
ABW[1]	**Day 0**	41.1^{a}	38.0^{b}	0.3	39.5	39.6	0.3	41.4	40.8	37.6	38.4	0.4	**<0.001**	0.80	0.11
	Day 8	179^{a}	145^{b}	3	159	165	3	178	181	140	151	5	**<0.001**	0.17	0.42
	Day 17	608^{a}	421^{b}	6	505^{b}	524^{a}	6	593	622	417	425	8	**<0.001**	**0.03**	0.21
	Day 23	1039^{a}	683^{b}	10	845^{b}	877^{a}	10	1012	1066	678	689	14	**<0.001**	**0.03**	0.13
	Day 29	1558^{a}	994^{b}	14	1255^{b}	1298^{a}	14	1519	1599	991	997	20	**<0.001**	**0.04**	0.08
	Day 38	2473^{a}	1568^{b}	18	1973^{b}	2067^{a}	18	2405	2541	1541	1594	25	**<0.001**	**0.001**	0.11
	Day 44		2014	11	1963^{b}	2066^{a}	16							**<0.001**	
	Day 53		2667	14	2590^{b}	2744^{a}	20							**<0.001**	
ADG[2]	**0−8 d**	17.3^{a}	13.4^{b}	0.4	14.9	15.7	0.4	17.0	17.5	12.8	14.0	0.6	**<0.001**	0.17	0.50
	8−17 d	47.6	30.7	0.4	38.4	39.8	0.4	46.1^{b}	49.1^{a}	30.8^{c}	30.5^{c}	0.6	**<0.001**	**0.03**	**0.01**
	17−23 d	71.9^{a}	43.7^{b}	1.0	56.7	58.9	1.0	69.9	73.9	43.5	43.9	1.5	**<0.001**	0.15	0.22
	23−29 d	86.6^{a}	51.8^{b}	1.2	68.3	70.1	1.2	84.5	88.7	52.1	51.4	1.7	**<0.001**	0.31	0.16
	29−38 d	101.8^{a}	63.7^{b}	1.0	79.7^{b}	85.7^{a}	1.0	98.4	105.2	61.1	66.3	1.4	**<0.001**	**<0.001**	0.62
	38−44 d		74.1	0.9	69.5^{b}	78.7^{a}	1.2							**<0.001**	
	44−53 d		72.5	0.9	69.7^{b}	75.3^{a}	1.2							**0.01**	
ADFI[3]	**0−7 d**	18.6^{a}	15.5^{b}	0.4	16.4^{b}	17.7^{a}	0.4	17.9	19.3	14.9	16.1	0.6	**<0.001**	**0.04**	0.92
	8−16 d	61.3^{a}	42.9^{b}	0.6	51.4	52.8	0.6	60.1	62.4	42.7	43.2	0.8	**<0.001**	0.09	0.28
	17−22 d	105.0^{a}	68.9^{b}	1.2	85.2^{b}	88.7^{a}	1.2	102.1	107.8	68.3	69.6	1.7	**<0.001**	**0.05**	0.21
	23−28 d	141.9^{a}	93.9^{b}	1.0	115.4^{b}	120.5^{a}	1.0	137.8^{b}	146.0^{a}	92.9^{c}	94.9^{c}	1.4	**<0.001**	**0.002**	**0.04**
	29−37 d	158.1^{a}	114.0^{b}	1.1	132.1^{b}	140.1^{a}	1.1	153.1	163.1	111.1	117.0	1.5	**<0.001**	**<0.001**	0.19
	38−43 d		142.0	0.9	136.1^{b}	147.8^{a}	1.2							**<0.001**	
	44−53 d		145.9	1.1	141.4^{b}	150.4^{a}	1.6							**0.002**	
FCR[4]	**0−7 d**	1.11^{b}	1.20^{a}	0.01	1.13^{b}	1.18^{a}	0.01	1.09	1.13	1.17	1.23	0.01	**<0.001**	**0.002**	0.36
	8−16 d	1.29^{b}	1.41^{a}	0.01	1.35	1.34	0.01	1.30	1.27	1.39	1.42	0.01	**<0.001**	0.78	0.07
	17−22 d	1.47^{b}	1.59^{a}	0.01	1.53	1.53	0.01	1.47	1.46	1.59	1.59	0.02	**<0.001**	0.85	0.69
	23−28 d	1.62^{b}	1.78^{a}	0.02	1.70	1.71	0.02	1.61	1.64	1.78	1.77	0.03	**<0.001**	0.72	0.41
	29−37 d	1.69	1.73	0.02	1.72	1.71	0.02	1.68	1.70	1.76	1.71	0.02	0.07	0.53	0.19
	38−43 d		1.91	0.01	1.91	1.90	0.01							0.71	
	44−53 d		2.14	0.02	2.13	2.14	0.02							0.59	
	FCR total	1.51^{b}	1.77^{a}	0.01	1.64	1.64	0.01	1.51	1.51	1.77	1.77	0.01	**<0.001**	0.98	0.78

a−c Values in a row for each variable lacking a common superscript differ significantly ($P < 0.05$).

[1] ABW = average body weight (gram).

[2] ADG = average daily gain of BW per broiler (gram).

[3] ADFI = average daily feed intake per broiler (gram).

[4] FCR total is the total feed conversion ration calculated over the whole growing period.

Table 3
Effects of strain, enrichment and strain * enrichment interaction, age and observation session on group behaviour, shown as least square means and pooled SEM. Data are expressed as % of broilers showing a certain behaviour. FAST = fast-growing broiler, SLOW = slower-growing broiler; EE = enriched pen; NE = non-enriched pen. At 45 days of age only SLOW broilers were in the experiment.

Days of age		9, 24 and 31 days of age					45 days of age				
Behaviour (%)		Sit idle	Stand idle	Ingest[1]	Active[2]	Comfort[3]	Sit idle	Stand idle	Ingest[1]	Active[2]	Comfort[3]
Strain	FAST	59.9^{a}	3.1	12.0^{a}	14.0^{b}	11.0					
	SLOW	55.7^{b}	6.2	9.2^{b}	18.5^{a}	10.5					
	SEM	1.4	0.4	0.7	0.9	0.4					
Enrich-ment	EE	59.0	4.1	9.8	16.6	10.4	71.6	3.8	3.7	12.7^{a}	6.9
	NE	56.6	5.1	11.4	15.8	11.0	73.7	3.7	4.8	8.5^{b}	9.2
	SEM	1.4	0.4	0.7	0.9	0.4	1.9	0.5	1.0	1.1	0.9
Strain * enrichment	EE – FAST	59.6	3.4^{bc}	11.2	15.4	10.4					
	NE – FAST	60.3	2.7^{c}	12.9	12.5	11.6					
	EE – SLOW	58.5	4.8^{b}	8.4	17.8	10.5					
	NE - SLOW	53.0	7.5^{a}	10.0	19.1	10.4					
	SEM	2.0	0.6	0.9	1.3	0.6					
Session	Morning	57.9	4.1	10.0	16.7	11.1	72.9	3.4	4.2	10.7	7.5
	Afternoon	57.7	5.1	11.1	15.7	10.3	72.4	4.1	4.3	10.5	8.7
	SEM	1.3	0.4	0.6	0.8	0.4	2.1	0.6	0.9	1.2	1.0
Age	9 days	42.7^{b}	7.1^{a}	17.7^{a}	22.9^{a}	9.6^{b}					
	24 days	64.5^{a}	4.2^{b}	7.9^{b}	12.1^{b}	11.2^{ab}					
	31 days	66.2^{a}	2.5^{b}	6.2^{b}	13.6^{b}	11.4^{a}					
	45 days										
	SEM	1.8	0.5	0.8	1.1	0.5					
P-value	P_{strain}	**0.05**	**<0.001**	**0.003**	**<0.001**	0.38					
	$P_{enrichment}$	0.24	0.77	0.08	0.52	0.33	0.45	0.97	0.46	**0.05**	0.11
	$P_{strain*enrichment}$	0.14	**<0.001**	0.95	0.11	0.28					
	$P_{session}$	0.90	0.48	0.11	0.33	0.18	0.89	0.52	0.92	0.94	0.47
	P_{age}	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.03**					
	$P_{age*strain}$	0.15	**0.02**	–	0.68	–					
	$P_{age*enrichment}$	0.85	0.30	–	0.42	**<0.001**					
	$P_{age*strain*enrichment}$	**0.006**	**0.02**	–	**0.03**	–					

[a–b]Per factor, values in a column lacking a common superscript differ (P < 0.05);
[1] Sum of behaviours eating and drinking.
[2] Sum of behaviours locomotion, sitting and ground pecking, foraging, aggression and others.
[3] Sum of dustbathing and comfort behaviour.

where age effect was prominent. At d 9, less sitting idle and more standing idle and active behaviour was observed compared to d 24 and 31, regardless of strain or enrichment. An interaction between age and enrichment ($P < 0.05$; data not shown) was found for comfort behaviours. At d 9 broilers EE pens showed less comfort behaviours as compared to broilers in EE pens at d 24 or broilers in NE pens at d31.

Supplementary Table 1 presents the results when FAST and SLOW were compared at equal body weight (d 24 for FAST, d 31 for SLOW; ±1.1 kg). An interaction of strain and enrichment was found for sitting idle and comfort behaviour. NE-SLOW showed least sitting idle and NE-FAST most (Δ = +8.9 %) with EE-FAST and EE-SLOW in between ($P = 0.004$). EE-SLOW showed least comfort behaviour and NE-SLOW most (Δ = +3.2 %) with NE-FAST and EE-FAST in between ($P = 0.04$). Further, SLOW broilers showed more standing idle (Δ = +1.9 % ; $P = 0.002$) and active behaviour (Δ = +4.0 %; $P = 0.004$) than FAST, whereas FAST showed more ingestion behaviour than SLOW (Δ = +4.1 %; $P < 0.001$).

3.2.2. *Focal sampling*

Results for focal sampling (comparing treatments at the same age) are shown in Table 4. No significant interactions between strain and enrichment were found. A significant strain effect was found for the time spent active on d 10, 25 and 32, with SLOW broilers being more active than FAST broilers (Δ = 4.5 %; $P = 0.05$). Enrichment also affected the time being active; broilers in EE pens showed a longer duration of active behaviours compared to broilers in NE pens on d 10, 25 and 32 (Δ = +11.3 %, $P = 0.03$). A longer duration of resting was found in the afternoon compared to the morning on d 10, 25 and 32 ($P = 0.007$). Age effects ($P < 0.01$) were found for the time spent standing, sitting and active. Broilers stood longer at d10 compared to older broilers (d 25 and 32), whereas at d 25 and 32 broilers sat longer than at d 10. Further, more active behaviour was observed at d 10 compared to d 25 and 32.

Supplementary Table 2 presents the results when FAST and SLOW were compared at equal body weight (d 25 for FAST, d 32 for SLOW; ±1.1 kg). Also here, no significant interaction between strain and enrichment was found. Strain significantly affected the time spent active with SLOW being more active than FAST (Δ = +7.2 %; $P = 0.04$). Time spent on ingestion behaviours was significantly higher for NE compared to EE (Δ = +7.5 %; $P = 0.05$).

3.2.3. *Enrichment use*

Results when treatments are compared at the same age are shown in Table 5. Percentages of total enrichment use (Δ = +13.5 %), use of the area on the ramp/platform (Δ = +5.2 %) and perch use (Δ = +10.9 %) were significantly higher for SLOW broilers than for FAST broilers ($P < 0.005$). At d 9, 24 and 31, platform/ramps were used more in the afternoon whereas the dustbathing area was used more in the morning than in the afternoon ($P < 0.05$). At d24 broilers showed higher percentages of total enrichment use compared d9 and 31 of age ($P < 0.001$). The area under the ramp/platform was more used at d 24 than at d 31 of age ($P = 0.02$) (Table 5).

Supplementary Table 1 shows enrichment use for FAST and SLOW compared at equal body weight (d 24 for FAST, d 31 for SLOW; ±1.1 kg). At equal body weight, more FAST broilers were sitting under the ramp/platform (Δ = +13.5 %; $P < 0.001$) than SLOW broilers, whereas more SLOW birds were sitting on the perch than FAST broilers (Δ = +9.9 %; $P < 0.001$). A session effect was found for the proportion of broilers perching, with more broilers perching in the afternoon than in the morning ($P = 0.02$).

Table 4
Effects of strain, enrichment, the interaction between strain and enrichment, age and observation session on the duration of individual behaviour, shown in least square means and (pooled) SEM. Data are expressed as percentage of time spent on a behaviour. FAST = fast-growing broiler, SLOW = slower-growing broiler; EE = enriched pen; NE = non-enriched pen. At 46 days of age only SLOW broilers were in the experiment.

Days of age		10, 25, and 32 days of age						46 days of age					
Variable (%)		Sit[1]	Stand[1]	Ingest[2]	Active[3]	Rest[4]	Comfort[5]	Sit[1]	Stand[1]	Ingest[2]	Active[3]	Rest[4]	Comfort[5]
Strain	FAST	78.4	21.6	12.8	9.7^{b}	68.8	8.8						
	SLOW	76.9	23.1	8.0	14.2^{a}	72.3	5.5						
	SEM	2.5	2.5	1.9	1.8	2.7	1.2						
Enrich-ment	EE	80.0	20.0	8.0	17.6^{a}	67.9	6.6	88.4	11.6	2.0	10.4	81.9	5.7
	NE	75.3	24.7	12.8	6.3^{b}	73.2	7.7	79.1	20.9	5.6	3.7	82.4	8.3
	SEM	2.5	2.5	1.9	1.8	2.7	1.2	4.7	4.7	2.4	3.5	5.4	3.2
Strain * enrichment	EE - FAST	80.7	19.3	9.9	13.1	67.5	9.5						
	NE - FAST	76.1	23.9	15.7	6.2	70.1	8.0						
	EE - SLOW	79.4	20.6	6.1	22.0	68.3	3.6						
	NE - SLOW	74.5	25.5	10.0	6.3	76.3	7.4						
	SEM	3.6	3.6	2.6	2.6	3.8	1.7						
Session[4]	Morning	74.9	25.1	11.7	14.1	65.6^{b}	8.6	85.5	14.5	4.3	7.2	83.5	5.0
	Afternoon	80.5	19.5	9.1	9.8	75.5^{a}	5.7	82.0	18.0	3.3	6.9	80.8	9.0
	SEM	2.4	2.4	1.8	1.8	2.6	1.2	4.7	4.7	2.4	3.5	5.4	3.2
Age[5]	10 days	68.4^{b}	31.6^{a}	15.8^{a}	12.0^{a}	66.5	5.6						
	25 days	82.6^{a}	17.4^{b}	6.0^{b}	11.9^{b}	73.7	8.3						
	32 days	81.9^{a}	18.1^{b}	9.4^{b}	11.8^{b}	71.4	7.5						
	46 days												
	SEM	3.1	3.1	2.3	2.2	3.3	1.5						
P-value	P_{strain}	0.69	0.69	0.06	**0.05**	0.37	0.18						
	$P_{enrichment}$	0.19	0.19	0.10	**0.03**	0.17	0.27	0.18	0.18	0.38	0.88	0.95	0.92
	$P_{strain*enrichment}$	0.96	0.96	0.88	0.44	0.48	0.47						
	$P_{session}$	0.10	0.10	0.53	0.27	**0.007**	0.06	0.60	0.60	0.43	0.76	0.73	0.35
	P_{age}	**0.003**	**0.002**	**0.004**	**0.002**	0.30	0.34						

a–b Per factor, values in a column lacking a common superscript differ ($P < 0.05$);
1 Sitting and standing posture; irrespective of the behaviour performed during sitting and standing.
2 Sum of eating and drinking.
3 Sum of locomotion, perching, fighting, scratching, ground pecking, jumping, flying, wing flapping, aggression and others.
4 Sum of standing and sitting idle.
5 Sum of behaviours preening, dustbathing and stretching.

3.3. *Gait score, footpad dermatitis and hock burn*

No significant effect of strain and enrichment or interaction effects were found for gait score, FPD and HB at d 31, 37 and 51 (Table 6).

4. Discussion

A combination of various environmental enrichments as applied in the present study increased in both fast- and slower-growing broiler chickens the time spent on active behaviour when compared at similar ages. An increase in the proportion of active chickens on d 45 was observed for the slower-growing strain in the enriched environment. However, no effect of enrichment on walking ability and contact dermatitis was found, and performance was negatively affected by the applied enrichments in both strains.

4.1. *Enrichment use and behaviour*

Enrichment use was measured for the platform, barrier perches and dustbathing area. More slower-growing broilers were observed on the

Table 5
Effect of strain, observation session and age on use of pen enrichment, shown as least square means and (pooled) SEM of % of broilers using the particular enrichment. FAST = fast growing broilers; SLOW = slower growing broilers. At 45 days of age only SLOW broilers were present.

Days of age		Overall of 9, 24, and 31 days of age					45 days of age				
Variable (%)		Area on ramp /platform	Area under ramp/ platform	Dustbath in area	On perch	Total use of enrichment[1]	Area on ramp /platform	Area under ramp/ platform	Dustbath in area	On perch	Total use of enrichment[1]
Strain	FAST	12.7^{b}	36.3	1.3	4.2^{b}	54.5^{b}					
	SLOW	17.9^{a}	33.7	1.3	15.1^{a}	68.0^{a}					
	SEM	1.2	1.6	0.3	1.0	1.8					
Session	Morning	13.8^{b}	35.5	2.0^{a}	11.1	62.4	18.0	35.1	0.4	13.6	66.7
	Afternoon	16.7^{a}	34.5	0.6^{b}	8.2	60.1	19.3	40.0	1.4	9.9	70.1
	SEM	1.1	1.4	0.3	0.9	1.7	2.2	3.2	0.5	1.4	3.3
Age	9 days	15.2	34.1^{ab}	1.1	6.3^{b}	56.6^{b}					
	24 days	15.8	39.3^{a}	2.0	13.0^{a}	70.2^{a}					
	31 days	14.8	31.5^{b}	0.7	9.8^{a}	56.9^{b}					
	SEM	1.5	2.0	0.4	1.2	2.2					
P-value	P_{strain}	**0.005**	0.28	0.27	**<0.001**	**<0.001**					
	$P_{session}$	**0.04**	0.57	**0.01**	0.29	0.31	0.67	0.20	0.22	0.08	0.50
	P_{age}	0.89	**0.03**	0.16	0.82	**<0.001**					

a–b Per factor, values within a column lacking a common superscript differ ($P < 0.05$);
1 Sum of % of chickens using the various enrichment materials.

Table 6
Effects of strain, enrichment and strain*enrichment interaction on gait score, footpad dermatitis (FPD) and hock burns (HB). FAST = fast growing broilers, SLOW- = slower growing broilers, NE = non enriched pen, EE = enriched pen. Data shown as means and pooled SEM of the scores.

Days of age		Day 31[1]			Day 37[1]			Day 51[1]		
Variable		Gait[2]	FPD[3]	HB[3]	Gait[2]	FPD[3]	HB[3]	Gait[2]	FPD[3]	HB[3]
	FAST	2.38	0.05	0.10	2.21	0.02	0.07			
Strain	SLOW				1.83	0.00	0.00	2.33	0.00	0.07
	SEM	0.10	0.03	0.04	0.05	0.02	0.02	0.07	0.00	0.04
	EE	2.19	0.05	0.10	1.95	0.00	0.05	2.19	0.00	0.14
Enrichment	NE	2.57	0.05	0.10	2.10	0.02	0.02	2.48	0.00	0.00
	SEM	0.12	0.05	0.06	0.07	0.02	0.03	0.08	0.00	0.03
	EE - FAST	2.19	0.05	0.10	2.19	0.00	0.10			
	NE - FAST	2.57	0.05	0.10	2.24	0.05	0.05			
Strain*enrichment	EE - SLOW				1.71	0.00	0.00	2.19	0.00	0.14
	NE- SLOW				1.95	0.00	0.00	2.48	0.00	0
	SEM	0.12	0.05	0.06	0.07	0.06	0.02	0.08	0.00	0.03
	P_{strain}				0.12	1.00	1.00			
P-value	$P_{enrichment}$	0.35	0.48	0.85	1.00	1.00	1.00	1.00	1.00	1.00
	$P_{strain*enrichment}$				0.21	1.00	1.00			

[1] BW at d31: ± 1600 g (FAST); d37: ± 2400 g (FAST) or ± 1600 g (SLOW); d51 ± 2500 g (SLOW).
[2] Gait scores on a 0–5 scale according to Welfare Quality (2009), with 0 being perfect walking and 5 being unable to walk.
[3] FPD and HB scored on a 0–4 scale, based on severity of the lesions, with 0 being no lesion and 4 being a severe lesion, according to Welfare Quality (2009).

barrier perches than fast-growing broilers, and also at an equal body weight of 1.1 kg more slower-growing broilers were perching than fast-growing broilers; regarding platform use, a tendency was found for more slower-growing broilers using the platform. This confirms earlier studies indicating that slower-growing broilers make more use of environmental enrichments compared to fast-growing broilers (Bokkers and Koene, 2003; Riber et al., 2018; Malchow et al., 2019; Rayner et al., 2020). The higher use of platforms and perches of slower-growing compared to fast-growing broilers could be caused by their higher activity level in general (Bokkers and Koene, 2003; Yngvesson et al., 2016; Dixon, 2020a), resulting in more slower-growing broilers climbing the ramp or perch. It could also be due to different body conformation compared to fast-growing broilers (e.g., Norring et al., 2016; De Jong and Gunnink, 2019), resulting in a better ability to fly or walk/climb on the platform or perch. This was also suggested by Malchow et al. (2019) who observed that, when offering platforms and perches at three levels, medium and slow-growing broiler chickens preferred the highest levels, whereas fast-growing broiler chickens preferred the lowest levels. This is further supported by our finding that more fast-growing broilers were on the platforms than on the barrier perches, as was also found in previous studies showing that platforms are the preferred elevated resting structure for fast-growing broiler chickens (Norring et al., 2016; Kaukonen et al., 2017; Bailie et al., 2018). In contrast, slower-growing broilers did not seem to have a preference for platforms over perches until d 31, but around slaughter age (d 45 of age), thus at higher body weights, slower-growing broilers also seemed to prefer the platform over the perches. Thus, platforms might be preferred by fast-growing broilers and older slower-growing broilers as they have fewer problems with finding their balance when resting on platforms in comparison to perches, or, walking a ramp to access a platform is easier than jumping on a perch at a higher body weight. Only minor effects of observation session were found with a slightly higher proportion of broilers on the platform and a lower proportion of broilers in the dustbathing area in the afternoon as compared to the morning, which could have been caused by insect feeding in the dustbathing area in the morning. It cannot be excluded that larger session effects would have been found when the second observation period was planned in the late instead of the early afternoon.

Previous studies have shown that providing a separate dustbathing area with moss-peat stimulated dustbathing and foraging behaviour in fast-growing broiler chickens (Baxter et al., 2018a). However, in the present study, providing these enrichments did not affect comfort behaviours (i.e. preening, stretching and dustbathing) in this specific area, nor did strain have an effect on this. Dustbathing frequency is generally low (Shields et al., 2004) and peaks around noon (Vestergaard et al., 1990), meaning that our observation method might not have been suitable to find any effects of the enrichment and/or strain on dustbathing. Another explanation might be that we provided the BSFL in the dustbathing area, which stimulated foraging behaviour in this specific area and might have made this area less attractive for dustbathing.

A significant interaction between enrichment and strain (compared at similar ages) was found for the proportion of chickens standing idle, with enrichment reducing the proportion standing idle in slower-growing chickens but having no effect on the proportion fast-growing chickens standing idle. Results indicate that more slower-growing chickens were sitting idle in the enriched environment, although differences were not significant, likely stimulated by the perches and platforms meeting the needs for resting on an elevated structure. The reduction in proportion of chickens standing idle due to enrichment was not observed in the fast-growing chickens, where standing idle was observed less frequently anyway, likely because fast-growing chickens have more difficulties to stand due to their higher body weight or different body conformation as compared to slower-growing broilers when compared at the same age (Bokkers and Koene, 2003). Comparing fast- and slower-growing chickens at an equal body weight of 1.1 kg showed similar results, where least sitting was observed in slower-growing broilers in the non-enriched environment as compared to all other treatment combinations, thus, indicating that the applied enrichments promoted sitting idle in slower-growing broiler chickens. A significant interaction between strain and enrichment, compared at an equal body weight of 1.1 kg, was also found for the proportion of chickens showing comfort behaviour. In enriched pens, more fast-growing broilers showed comfort behaviours compared to the non-enriched pens, whereas for slower-growing broilers the opposite effect was found. Thus, compared at the same body weight, the applied enrichments had some different effects on fast- and slower-growing broilers and mainly promoted sitting idle in slower-growing broilers. So, contrast to our hypothesis, environmental enrichment did not increase activity to a larger extent in slower-growing broilers than in fast-growing broilers, despite the fact that they made better use of the provided enrichments. This was likely caused by our choice to include enrichments suitable for resting behaviours (i.e. platforms and perches). These were well used by the slower-growing broilers and although this indicates that these enrichments meet their behavioural requirements, it might have reduced the total time spent on active behaviours or proportion of chickens showing active behaviours. It remains to be further investigated whether or not our hypothesis that environmental enrichment has a larger effect on activity in slower-growing as compared to fast-growing broilers is confirmed when only enrichments stimulating active behaviours are included.

Despite the absence of an interaction between strain and enrichment, providing enrichments increased the time spent active until d 31 in both strains and the proportion of slower-growing chickens being active at d 45. Inconsistent effects of different types of environmental enrichment on general activity have been found in previous studies (Riber et al., 2018). For example, Bach et al. (2019) showed that the proportion of fast-growing chickens being active only seemed to increase with an increased distance between feeders and drinkers in the first two weeks of life, whereas enrichments, such as platforms, roughage and straw bales did not increase the proportion of chickens being active. Furthermore, they showed that specific behaviours were stimulated by specific enrichments, such as resting, locomotion and standing with platforms and foraging with roughage. As we combined different types of enrichments, we cannot relate the increase in activity to one of the enrichments. Feeding live insects has been shown to stimulate foraging activity in chickens (Pichova et al., 2016; Ipema et al., 2020b). Observations around the time of insect feeding in the current study confirmed that all chickens were very eager to consume the insects and that providing the live insects stimulated foraging and locomotion, although this effect mainly seemed to be present shortly after providing the insects. Indeed, Ipema et al. (2020a) showed that providing live insects increased the activity of broiler chickens around the time of provision and general activity level (Ipema et al., 2020a, b). However, in their studies, insects were provided at least twice a day or continuously by using a feeding tube, which could have increased the effect on broiler activity in comparison to our study. In addition to insect feeding, the longer distance between feed and water in the current study likely contributed to the increased duration of chickens being active in enriched pens, as it has been found that this stimulates locomotion in broiler chickens (Reiter and Bessei, 2009; Bach et al., 2019). Although climbing the ramps to the platforms and crossing the barrier perches to reach feed and water stimulates specific physical activities, it is less likely that these contributed to the increased duration of being active in the enriched pens as these types of enrichments also stimulate resting behaviour (Ventura et al., 2012; Bach et al., 2019). Thus, providing enrichments increased the time spent on active behaviours, potentially due to the provisioning of insects and increasing the distance between feed and water, and also had effect on the proportion of slower-growing chickens being active at d45 of age, which confirms our hypothesis that that the combination of enrichments as applied in this study could be effective to stimulate broiler chicken activity in general.

When comparing strains at the same ages, regardless of the environment, more slower-growing broilers were active and they also spent a longer time active, whereas more fast-growing broilers were observed sitting idle, eating and drinking. Similar effects were observed when comparing treatments at the same body weight of 1.1 kg. Our findings are supported by previous studies where fast-growing broilers showed more sitting, eating and drinking, but less active behaviours (i.e. locomotion, foraging) compared to slower-growing broilers (Bokkers and Koene, 2003; Wallenbeck et al., 2016; Dixon, 2020; Rayner et al., 2020). Fast- and slower-growing broilers are selected for a specific growth rate and differences between strains with regard to time budgets are most likely a result of growth or weight differences (Bokkers and Koene, 2003; Wallenbeck et al., 2016). Differences in activity might also be related with the presence of leg problems, since they may cause pain or physical limitations (Mc Geown et al., 1999; Weeks et al., 2000; Caplen et al., 2013; Hothersall et al., 2016). However, in the current study strains did not differ in gait scores, footpad dermatitis or hock burns. Overall, slower-growing broilers differed from fast-growing broilers in their time budget, showing more active behaviours and less eating and drinking, which is likely caused by selection on a slower or fast growth rate, respectively, resulting in differences in growth or body weight affecting performance of behaviours.

4.2. Walking ability and contact dermatitis

No significant interaction effect between strain and enrichment was found on the prevalence of contact dermatitis or walking ability, suggesting that providing enrichments did not affect these welfare measures in a different way for fast and slower-growing broilers. Surprisingly, strain did also not affect the prevalence of contact dermatitis or walking ability. Previously, slower-growing chickens had better leg health scores compared to fast-growing chickens (Dixon, 2020; Rayner et al., 2020). However, for hock burn and footpad dermatitis, the absence of a strain effect might have been caused by the very low scores in general, likely because the litter remained in a relatively good condition. For gait score, although a numerically lower gait score was found for the slower-growing chickens compared to the fast-growing chickens, scores were more or less similar for both strains at slaughter age, which is in contrast to other studies (Dixon, 2020; Rayner et al., 2020). Furthermore, higher average scores were found compared to commercial conditions as observed by Rayner et al. (2020). This could be explained by the fact that we included males only, that generally have higher gait scores compared to females (Dixon, 2020).

Providing enrichments did not affect the prevalence of contact dermatitis or walking ability. Previously it was suggested that perches and platforms give broilers an opportunity to rest without being in contact with litter, which could prevent contact dermatitis in fast-growing broilers (Ventura et al., 2010). Additionally, enrichments that promote litter scratching, such as providing insects, may improve litter quality and reduce the risk of contact dermatitis (Ipema et al., 2020a). However our findings contradict these hypotheses, but footpad dermatitis and hock burn scores were very low in the present study, which might have been caused by the conditions in the experimental pens not being sufficiently challenging to find effects of providing enrichments.

Furthermore, previous studies have shown that various types of environmental enrichment, such as (barrier) perches, platforms, straw bales, separation of resources and providing live insects can have a positive effect on walking ability and/or increase bone strength in fast-growing broiler chickens (Reiter and Bessei, 2009; Ventura et al., 2010; Kaukonen et al., 2017; Riber et al., 2018; Pedersen and Forkman, 2019; Ipema et al., 2020a). This is suggested to be caused by an increase in activity level of the chickens when provided with enrichment (Reiter and Bessei, 2009; Stojcic and Bessei, 2009; Pedersen and Forkman, 2019; Ipema et al., 2020a) or an increase in specific locomotor activities, such as walking up and down and jumping, that may stimulate bone strength (Kaukonen et al., 2017), although not all studies found these effects (Bailie et al., 2018; Riber et al., 2018; Pedersen and Forkman, 2019; Pedersen et al., 2020). The discrepancy between the various studies might be related to the actual use of enrichment and the extent to which it promotes activity of the chickens, which is related to the type and amount of enrichment that also differs between studies. In the present study, we combined various enrichments that have been shown to be effective in stimulating broiler chicken activity and/or improving walking ability (Reiter and Bessei, 2009; Ventura et al., 2010; Norring et al., 2016; Pichova et al., 2016; Kaukonen et al., 2017; Baxter et al., 2018b; Bach et al., 2019; Ipema et al., 2020a) to achieve a maximum contrast between enriched and non-enriched broiler chickens. However, no significant effect of environmental enrichment on walking ability was found in both strains. This might be related to the relatively limited contrast in activity between enriched and non-enriched pens, which might have been related to our choice to include resting enrichments, as discussed above, although we did find some significant effects. Yet, Kaukonen et al. (2017) only provided elevated platforms and found a better leg health in broiler chickens, but no effect on total activity (Norring et al., 2016). They suggested that platforms stimulated different types of activity (jumping, climbing, walking up and down), even if these were mainly used for resting. In addition, they suggested that the broilers, housed under commercial conditions, were very eager to use the platforms and walked relatively long distances to reach these, despite the fact that they did not observe an effect on total activity. In the present study, we used small pens, which might explain the different findings compared to their study. Summarized, providing enrichments did not affect the prevalence of contact dermatitis or walking ability in the current study, potentially because of the types of enrichments provided and the limited, although sometimes significant, effect on time spent being active or the proportion of chickens being active, and, regarding contact dermatitis, the absence of challenging housing conditions.

4.3. Performance

It was not surprising that fast-growing chickens had a significantly higher daily body weight gain, a higher daily feed intake and a lower feed conversion ration compared to slower-growing chickens, since previous studies have reported the same (Dixon, 2020a). However, we observed a negative effect of environmental enrichment on performance in terms of feed intake and body weight gain. The impaired performance of chickens in enriched pens could have been caused by higher activity of enriched-housed chickens (Jordan et al., 2011) as providing enrichments increased the time spent being active in the present study. Differences in proportion of birds being active between enriched and non-enriched pens was relatively small, although at equal body weight a negative effect of enrichment on the proportion of chickens eating and drinking was found. More likely, one or more of the enrichments had a negative effect on feed intake and as a consequence on body weight gain. It has been previously shown that increasing the distance between feed and water reduced the number of chickens eating and drinking in the first weeks (Bach et al., 2019), although no negative effects on performance were found in that particular study (Jones et al., 2020). Bizeray et al. (2002b) did also not observe negative effects on performance when the distance between feed and water was increased. In the present study, not only the distance between feed and water was increased in the enriched pens, but also barrier perches were placed in between, which increased in height with age, thus, more effort was needed to move to the feeders and drinkers. Furthermore, if many chickens were resting on the barriers, this could have prevented other chickens to move to the feeders and drinkers. On the other hand, both Bizeray et al. (2002b) and Ventura et al. (2010) did not find any negative effects of barrier perches on performance. It can also not be excluded that the insect provision affected performance, despite the fact that we included pellets with similar energy and protein content in the diet of the non-enriched broilers. Interestingly, we observed many broilers standing without doing anything else in the period before the provision of insects. Possibly, this could have affected feed intake in the morning, before the provision of the insects. As insect feeding is a relatively new area and the effect on behaviour is not well known, this remains to be further studied. A possible solution to this effect of chickens ‘waiting’ for the insects is to provide these randomly instead of on a fixed time. Indeed, Ipema et al. (2020a) also observed that broilers were more active prior to the fixed provisioning times of live black soldier fly larvae, especially at young ages. Although a temporary negative effect was found on growth weight when 5 or 10 % of the diet was replaced by live black soldier fly larvae, final body weight was not affected Ipema et al. (2020b). Summarized, providing enrichments reduced performance in the current study, which could be due to increased activity, placement of barriers or insect provisioning, but the exact reason remains to be further studied.

5. Conclusions

In the present study, we provided both fast- and slower-growing broiler chickens with a combination of environmental enrichments, with the aim to stimulate their activity and as a consequence to improve leg health. Although the effect of enrichment on broiler activity was significant, effects were similar for fast and slower-growing broiler chickens, and no effect on walking ability or contact dermatitis prevalence was found. As some of the applied enrichments were mainly used for resting, which specifically seemed to be stimulated in slower-growing broilers, this could have affected the results of the present study and confirms earlier studies that different types of enrichment differentially affect activity and behaviour of broiler chickens. On the other hand, as the platforms and barrier perches were well used by broilers of both strains, these apparently met their requirements for an elevated resting area, and may thus have welfare benefits and should preferably be further tested under commercial conditions. As expected, slower-growing broiler chickens made more use of the provided enrichment than fast-growing broilers. It remains to be further studied which combination of environmental enrichment significantly stimulates both broiler activity and leg health in both fast- and slower growing broiler strains without compromising performance, as this will make it easier to implement the enrichments in commercial practice.

Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.applanim.2021.105375.

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